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CONTENTS

FOREWORD

Urban goods movement is the subject of the papers presented in this RECORD. A wide range of topics concerning the broad field of urban goods movement is covered. Transportation systems planners, engineers, and administrators should find these papers of significant interest.

In the first paper, Hutchinson examines the current capabilities of estimating urban goods movement demand. The principal concern of the paper is with the relationship between urban goods movement and the spatial arrangement of land uses. Hutchinson suggests that the spatial and temporal character of the urban freight movements is influenced by the intercity freight pricing regime. The results of a study of the truck generation rates of manufacturing industries in Toronto are provided.

In the second paper, de Neufville et al. investigate the desirability of consolidation terminals as a means to lower the cost of and ease the congestion caused by urban goods movement. This is done by using a detailed simulation of alternative configurations of pickup and delivery services, based on data obtained from operators of actual consolidation facilities. The alternatives analyzed are no consolidation, the prevailing mode of operation; route consolidation, which eliminates duplication in the pickup and delivery area; and complete consolidation using consolidation terminals.

In his paper, Starkie considers the bases of forecasts of urban truck activity made in the United Kingdom during the 1960s. Particular stress is placed on the importance of scaling factors, referred to as control totals. These control totals derive from estimates of national truck activity. Certain trends in the economy and, more specifically, significant changes in the productivity of the truck industry during the past few years appear to have been ignored in their development. The separate estimates made of zonal truck activity in transportation studies (estimates that are subject to the constraint imposed by the control totals) are characterized by poor statistical analyses. Starkie suggests that more attention be given to the development of adequate control totals and to methods of analysis that consider nonlinearities in zonal truck data.

McDermott and Robeson include in their study an examination of the vehicle characteristics of general freight pickup and delivery shipments of up to 5,000 lb that flow into and out of the Columbus, Ohio, CBD on a typical business day. The vehicle characteristics examined are number and types of vehicles; vehicle capacity utilization; distance traveled and air pollutants emitted within the CBD; aggregate daily transit, unloading, and loading time and queuing time prior to loading or unloading within the CBD; and pickup and delivery costs measured by applying a standard hourly cost to the total vehicle time within the CBD. The purpose of the study was to measure the effect that routing this daily demand through a consolidated terminal would have on these vehicle characteristics, by using the experimental technique of simulation. Data were collected through a cordon survey.

In the next paper, Meyburg, Lavery, and Parker consider the problems associated with the physical distribution of freight, as well as the problems of distribution center location. The authors suggest that these two areas of concern are very much intertwined such that they must be considered simultaneously as interrelated components of a single system. An extensive literature review of freight distribution and terminal location research is presented with special reference to the feasibility of designing a unified distribution system-terminal location theory.

Demetsky describes an analytical framework for summarizing representative small commodity movements among the firms, institutions, and households within an urban area. This methodology for measuring urban goods movements consists of a series of operations that process data on commodity shipments and the activity system to provide an input-output summary of selected urban commodity flows. Initially freight service zones are established for the study area, and classification systems are developed for commodity flow origins and destinations and for categories of small commodities. A direct firm-based commodity shipment survey procedure is recommended to obtain the essential planning data that are currently lacking on goods movement.

The purpose of the paper by Meyburg and Stopher is to establish principles and procedures for the analysis of demand for urban goods movements. A classification of freight movements is proposed, and attention is focused on the urban component of goods movements. The paper also establishes a case for research into urban freight demand and suggests strategies by which such a demand analysis could be initiated.

Arrow, Coyle, and Ketcham consider the environmental impact of urban goods movement in New York City. The authors examine the increasing reliance on the truck for the movement of goods and the adverse effects associated with trucks such as traffic congestion, increased energy consumption, increased noise and air pollution, broken and worn-out pavement, and high commodity costs. The authors suggest several strategies for reducing the impact of trucks on air quality.

Lea and Hartman review several Canadian urban goods movement research projects. An interim report is given on the Transportation Development Agency project, a long-range, multiphased program aimed at improving the movement of urban goods in Canadian cities. As a by-product of this work, a new urban goods classification system was developed in preliminary form and is discussed in this paper.

The paper by Wood describes the types of data required to deal with three different kinds of urban goods movement problems. The need for data on the major institutional problem in the freight field is also discussed.

Mohr, in the next paper, simplistically discusses five fallacies associated with urban goods movement: (a) all trucks are used to move goods; (b) congestion generated by urban goods movement in the CBD is on the increase; (c) consolidation of urban goods movement will produce major benefits for all concerned; (d) urban goods movement consolidation will relieve downtown congestion; and (e) urban goods movement can be improved by using rail transit facilities during off-peak hours. Mohr concludes that to retrofit existing rapid transit systems for goods movement appears futile and that even the design of future systems for dual use appears to be a mismatch for our motor vehicle-oriented metropolitan areas.

The last paper in this RECORD is a reevaluation of the activities of urban and regional transportation studies in dealing with freight transportation. Sullivan examines some problem areas that could be improved through the involvement of regional transportation planning agencies. He further argues that truck congestion is basically a localized phenomenon, most suitably analyzed within a framework far more detailed than a regional-level study. He concludes that other issues such as equitable cost allocation and the impact of pollution abatement costs are most suitably analyzed at the state or national level and that regional agencies should recognize this state of affairs and design their programs accordingly.

ESTIMATING URBAN GOODS MOVEMENT DEMANDS

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The current capabilities for estimating urban goods movement demands are examined. The demands are divided into three groups: goods movements between urban areas and external locations, interindustry goods movements within urban areas, and household-based goods movements. External goods movements may be grouped into direct consignments and consignments via freight terminals. Most direct consignments are by truck as are the pickup and delivery components of shipments via terminals. The spatial and temporal character of the urban components of the external freight movements is influenced by the intercity freight pricing regime. Commodity type, haul length, consignment weight, and plant size all influence intercity modal shipping decisions, and available data are presented. The interindustry input-output table presented may be used to estimate productions and attractions by commodity type. The normal interindustry table may be extended for urban areas to include sectors such as warehousing, wholesaling, and retailing. The spatial patterns of commodity movements may be estimated by a gravity model or a linear programming approach. The results of a study of truck trip generation rates of manufacturing industries in Toronto are provided.

•ONE of the findings of the Highway Research Board conference on urban commodity flow in 1970 (1) concerned the estimation of urban goods movement demands. The conference participants stated the requirements as follows (1, p. 2):

> Forecasts of urban goods movement should include a consideration of (a) changing patterns of urban development and structure; (b) locations of terminals and transfer points; (c) land use patterns; (d) changing economics... of the goods movement industry; (e) labor practices within the industry; (f) potential technological innovations in goods movement; (g) effects of governmental policy, financial aid, and regulation on the movement of goods; and (h) social and environmental considerations. Demand forecasting should portray the interrelationships among industry location, interindustry transactions, terminal interfaces, freight flow, mode choice and packing, and urban transportation network.

The purpose of this paper is to examine current capabilities of estimating urban goods movement demands. The principal concern is with the interrelationship of urban goods movement and the spatial arrangement of land uses. The paper contains material from already published sources as well as information generated by a number of research projects at the University of Waterloo.

CHARACTER OF URBAN GOODS MOVEMENT DEMANDS

Goods movement demands are created by the economic activities of production and consumption. Each unit of economic activity receives certain types of goods as input and dispatches other types as output. A useful way of thinking about urban goods movement problems is to relate urban goods movement demands to the internal economic structure of the principal economic units within urban areas.

Manufacturing plants receive inputs of raw materials and semifinished products and dispatch semifinished products and finished products to other plants—warehouses, retail outlets, and so on. Households receive inputs of food and other consumer products and dispatch garbage for disposal. Freight terminals receive either consignments that are consolidated into larger shipments for external destinations or consignments from external destinations that must be separated into smaller consignments for distribution within the urban area served by the terminal. Ready-mixed concrete plants receive inputs of cement, sand, and gravel and deliver concrete to construction sites. The amount of goods movement demand created by an economic unit is a function of the activities performed within that economic unit and the size of the unit.

To be useful, urban goods movement forecasting techniques must be developed in terms of fairly simple measures of economic activity, such as employment and population. Studies of person travel demands have shown that the determinants of this demand are relatively straightforward. Trip productions are normally explained in terms of zone populations, whereas trip attractions are usually related to various measures of employment.

The determinants of urban goods movement demands are more complex. An example of this complexity is given below. This table shows the tons of goods per employee per year that were required as input by various industries in Ontario in 1967.

Industry	Input Tons/Employee
Breakfast cereals	127
Steel pipe mills	186
Tobacco products	23
Cardboard boxes	51
Fabric gloves	0.2
Distilleries	232

This table shows that the goods requirements ranged from 0.2 ton per employee for fabric glove manufacturers to 232 tons per employee for distilleries. If goods movements are to be estimated properly, then a clear understanding of the internal structure of the various economic activities must be developed.

Another complication in estimation of goods movement demands is the variation in consignment size within one commodity classification. A manufacturer of consumer products might use a small truck to deliver local orders but might ship container-sized consignments only to customers located 1,000 to 2,000 miles away. The frequency distribution of consignment sizes for a particular firm might vary with the geographic size of the market served, which in turn may be dependent on the magnitude of the annual manufacturing output of the firm. That is, for any one commodity type there may be a number of consignment sizes that have very different transport needs.

A third complicating characteristic of goods movements is the frequency with which consignments are received and shipped. Shipping frequencies are clearly related to consignment sizes, which, as noted previously, are related to trip length. Shipment frequency may also be related to the amount of storage space at a particular plant or to capacities and load factors of the vehicles used for shipping consignments. In addition, for some commodities there may be seasonal variations in shipping frequencies.

CLASSIFICATION OF URBAN GOODS MOVEMENTS

Figure 1 shows a broad classification of the types of urban goods movements. Goods movements may be grouped initially as external-internal movements or as internal movements. External-internal goods movements may be thought of as being

1. Consignments that are shipped directly to or received directly from external locations or
2. Consignments that are shipped via some form of urban freight terminal.

Much of the freight that moves directly to and from urban economic units is carried by truck although many large firms have direct access to rail and in some cases to water transport. Goods that are shipped via freight terminals will involve a pickup or a delivery truck trip within an urban area.

Goods movements internal to an urban area may be grouped into two classes: interindustry and household-based. Interindustry movements of goods within urban areas include the distribution of semifinished products between plants and warehouses. Virtually all of the intraurban distribution of goods is accomplished by trucks of various sizes.

Household-based goods movements involve delivery of consumer goods, garbage disposal, and provision of various types of repair and maintenance services.

Each of these components of demand may be disaggregated by commodity type, consignment size, and shipping frequency. Each broad class of economic unit within an urban area will create different spatial pattern, commodity type, consignment size, and shipping frequency implications for the transport system.

A DEMAND FORECASTING FRAMEWORK

Figure 2 shows the flow of activities that may be used to estimate the goods movement demands in urban areas for industry units. Household-based demands are not included in the figure because they are relatively small. The first step suggested in Figure 2 is estimation of the annual production and consumption by commodity class by each economic unit, or group of units, within a zone of analysis. The figure indicates that the annual cash values of these productions and consumptions may be estimated from the employment by type and the per-employee productivities. Relevant information for Ontario manufacturing industries is presented in the following section.

The framework then suggests that the production and consumption linkages for any economic unit may be estimated from knowledge of the role that the economic unit plays in the national system of production and consumption. Figure 2 suggests that external-internal goods movements along with the internal interindustry movements may then be estimated directly from this type of analysis. It is suggested later in the paper that this analysis may be executed by using an input-output table in conjunction with a gravity model.

The relative proportions of external-internal consignments that are direct or via terminals are a consequence of the intercity modal shipping decisions made by the various economic units. These modal shipping decisions are a function of consignment size, consignment trip length, commodity, and intercity freight pricing regime. Available empirical evidence on intercity freight modal shipping decisions is presented later in the paper.

The annual demands for trucking by an economic unit may then be estimated from this modal-split analysis. Internal interindustry movements are virtually all by truck, and a modal-split analysis is not required. The conversion of the annual trucking demands to daily truck movements or demands over a shorter time period is a difficult and largely empirical problem. This conversion is influenced by many factors such as the split of demand between common and private carriers with their variations in load factors, variations in truck capacities, organizational structure within which a particular economic unit operates, and so on.

PRODUCTION AND CONSUMPTION LINKAGES

The flow of goods to, from, and within urban areas is a function of the national economic environment including the locations of centers of production and consumption. It has been suggested that the goods movement demands created by various types of economic units be estimated from a knowledge of the production and consumption characteristics of these units.

Kardosh and Hutchinson (2) have described the results of a truck trip generation study of some 250 manufacturing industries in metropolitan Toronto. As part of that study certain characteristics of the industries were observed including variables of the type normally reported in the Annual Census of Manufactures.

Table 1 gives the simple correlation matrix for the variables observed in this study for the 149 complete surveys returned. Of particular interest is the relationship between the total annual sales of goods and the various employment variables. Column 17 of Table 1 indicates that the manufacturing employment variables are highly related to annual sales as are total employment, total manufacturing man-hours per year, raw materials input for manufacture, and annual consumption of electricity.

Figure 1. Broad classification of urban goods movements.

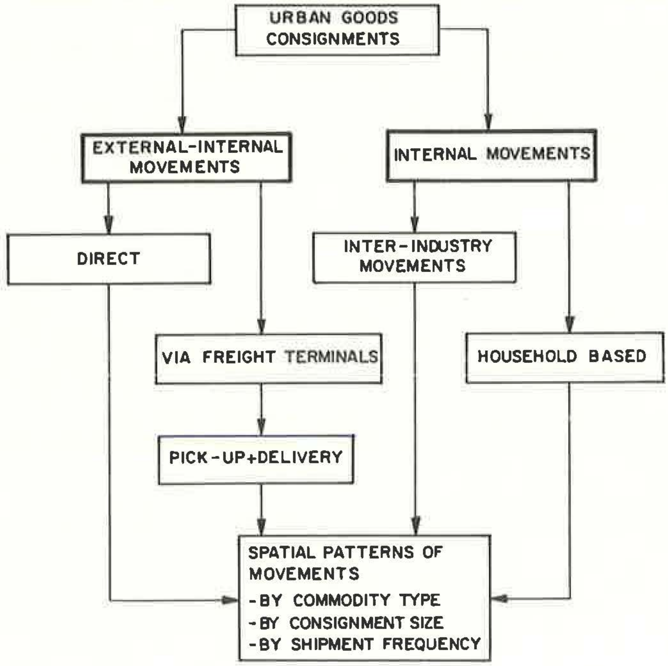
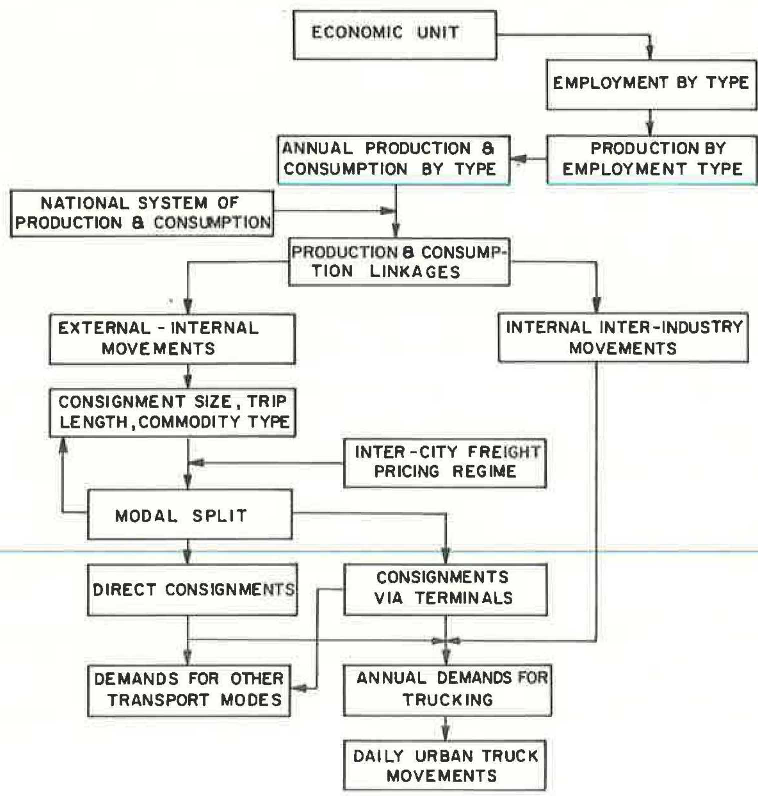


Figure 2. Industry-based urban goods movement demand forecasting framework.



A number of multiple linear regression equations have been fitted to the sales and employment data, and the two equations considered to be the best of those equations constructed are as follows:

$$P = 1487.9 + 55.99X_1 + 17.38X_2 \qquad R^2 = 0.733 \tag{1}$$

$$P = 141.7 + 28.57X_3 + 0.94X_4 \qquad R^2 = 0.811 \tag{2}$$

where

P = annual sales of goods in thousands of dollars (in 1970),
X_1 = male manufacturing employment,
X_2 = female manufacturing employment,
X_3 = total employment, and
X_4 = goods received for resale as such.

The partial regression coefficients of Eqs. 1 and 2 were found to be significant at the 1 percent level.

Equation 1 seems to be rational in terms of the relative magnitudes of the partial regression coefficients. Industries with large female manufacturing employment tend to be in the food, beverage, clothing, and electrical component assembly sectors where the value added during manufacturing is derived principally from labor inputs and little value derived from capital plant is added. In contrast, male manufacturing employment is concentrated in those sectors in which the majority of the value added during manufacturing is derived from capital plant. This is reflected in the partial regression coefficient of male manufacturing employment, which is about three times the coefficient for female employment.

Equation 2 provides a marginally better regression equation in which annual sales are expressed as a function of total employment and the goods received for resale. Many of the manufacturing industries in the Toronto region are subsidiaries of U.S. companies, and part of the function of many of these companies is to act as a warehouse for goods manufactured in the United States but sold in Canada. The equation seems to be rational except that the partial regression coefficient of goods for resale should be at least equal to 1.0. The partial regression coefficient of total employment is reasonable and is supported by evidence available from other sources. Equations 1 and 2 suggest that reasonably accurate estimates of annual productivities by industry type may be obtained from fairly coarse measures such as total employment. Regression equations could be developed separately for each industry category, inasmuch as variations in the magnitudes of the partial regression coefficients between industry types might be expected.

An attempt was made to relate the variable goods received as such to the various employment variables, but a statistically valid equation could not be developed. The value of raw material received as input has been analyzed with respect to the employment variables and the most satisfactory relationship developed is

$$C = 1196.6 + 16.81X_1 \qquad R^2 = 0.600 \tag{3}$$

where C = annual input of raw materials for manufacturing in thousands of dollars in 1971.

Equation 3 is not so satisfactory as the equations developed for estimating total sales of goods. In addition, the commodity inputs to many manufacturing establishments are much more heterogeneous than the outputs. A useful tool for highlighting the consumption characteristics of various industry categories is the input-output table. Its use for commodity flow estimation has been proposed by a number of investigators (3, 4, 5, 6). Estimates of the annual inputs by industrial sector to industries of a particular type in a specific geographic zone may be obtained from

$$a_j^e = \{a_{er}\}p_j^e \tag{4}$$

Table 1. Simple correlation matrix for variables that describe size of manufacturing establishments.

Variable	Variable Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Total manufacturing employment	1.00	0.929	0.650	0.225	0.798	0.828	0.667	0.600	0.967	0.950	0.754	-0.013	0.851	0.619	0.090	0.749	0.842
2. Male manufacturing employment		1.000	0.381	0.304	0.781	0.809	0.653	0.445	0.917	0.917	0.775	-0.006	0.806	0.666	0.120	0.842	0.845
3. Female manufacturing employment			1.000	-0.024	0.479	0.493	0.410	0.556	0.592	0.577	0.367	-0.019	0.508	0.280	-0.007	0.238	0.450
4. Sales and distribution employment				1.000	0.374	0.302	0.470	0.037	0.357	0.247	0.298	0.115	0.066	0.230	0.079	0.238	0.230
5. Total office employment					1.000	0.982	0.936	0.485	0.902	0.807	0.637	0.081	0.654	0.579	0.086	0.580	0.729
6. Male office employment						1.000	0.852	0.506	0.911	0.842	0.642	0.059	0.705	0.577	0.101	0.606	0.748
7. Female office employment							1.000	0.400	0.798	0.664	0.566	0.112	0.496	0.527	0.050	0.474	0.622
8. Professional and technical employment								1.000	0.630	0.604	0.443	0.114	0.593	0.466	-0.003	0.200	0.608
9. Total employment									1.000	0.942	0.757	0.056	0.809	0.660	0.101	0.708	0.850
10. Total manufacturing man-hours/year										1.000	0.732	0.007	0.845	0.612	0.092	0.743	0.833
11. Raw material input for manufacture											1.000	0.002	0.786	0.499	0.154	0.663	0.773
12. Resale goods as such												1.000	0.016	0.281	-0.047	-0.047	0.343
13. Highest monthly inventory of raw materials													1.000	0.544	0.103	0.717	0.815
14. Highest monthly inventory of finished products														1.000	0.113	0.576	0.770
15. Annual fuel consumption															1.000	0.099	0.025
16. Annual electricity consumption																1.000	0.735
17. Annual total sales of goods																	1.000

Table 2. Part of direct requirements matrix of Ontario input-output table.

Industry Sector	Industry Number 24	25	26	27	28	29
24. Printing, publishing	0.034451	0.000144	0.000030	0.0	0.000629	0.000515
25. Iron, steel mills	0.0	0.185166	0.047004	0.358441	0.396149	0.158633
26. Other primary metals	0.000457	0.019122	0.327892	0.005927	0.056476	0.130246
27. Fabricated and structural metals	0.000342	0.0	0.0	0.0	0.0	0.013028
28. Metal stamping, etc.	0.000034	0.000031	0.004292	0.0	0.000036	0.006945
29. Other metal fabric. ind.	0.002897	0.003131	0.039306	0.035729	0.056490	0.077058
50. Wages and salaries	0.394777	0.203510	0.238601	0.252745	0.203964	0.258327
51. Other valued added	0.150277	0.294799	0.111362	0.247984	0.145281	0.127002

Table 3. Part of Stockholm input-output table (in millions of Swedish crowns, 1950).

Input Sector	Output Sector 35	36	37	38	40	41	42	43	44	45
37	25.1	9.8	5.0						0.2	
38	0.7	0.5		1.2						
39										
40					0.2					
41						1.9				
42	0.7	0.5					14.0	3.6	14.9	0.3

Note: 35. building construction;
36. construction other than building;
37. wholesale trade: hardware, lumber, construction materials;
38. wholesale trade: fuels;
39. wholesale trade: shop and office fittings;
40. wholesale trade: machinery, equipment, and supplies;
41. wholesale trade: pump, paper and paper products;
42. wholesale trade: other kinds of business;
43. retail trade: motor vehicles;
44. retail trade: other consumers' durables; and
45. retail trade: department and variety stores.

Table 4. Observed and estimated inputs to Ontario brewing industry, 1970.

Input-Output Sector	Observed Input Values (thousands of dollars)	1965 Technical Coefficients	Estimated Input Values (thousands of dollars)	Estimated/ Observed
1. Agriculture	1,142.7	0.006485	1,085.5	0.95
6. Nonmetals mining	13.9	0.000038	6.4	0.46
14. Grain mills	1,805.4	0.005428	908.5	0.50
19. Miscellaneous food products	13,291.0	0.089024	14,902.9	1.12

where

a_j^e = a column vector of the annual consumption by commodity type e by industries in zone j,

$\{a_{ef}\}$ = the direct requirements matrix of the input-output table for the e input industries and the f output industries, and

p_j^e = a column vector of the cash values of the annual production by commodity type e in region j.

The cash values may be converted into physical units by the use of producers' prices. Estimates of production for future years may be made from a knowledge of the expected employment levels by type in each analysis zone by using relationships of the type introduced previously.

Table 2 gives part of the direct requirements matrix of the Ontario input-output table (7). The cells of the matrix show the dollar value of inputs required by the industry named at the top of the column to produce $1 of total output. For example, the metal stamping, pressing, and coating industry (No. 28) requires 39.6 cents of input from iron and steel mills, 20.4 cents in salaries and wages, and 14.5 cents of input from capital facilities to produce $1 of total output. In contrast, the printing and publishing industry requires no input from iron and steel mills but 39.5 cents of labor input.

The input-output table format concentrates on the manufacturing industry sectors. The input-output table may be extended readily to include other sectors important to urban goods movement such as warehousing, retailing, and downtown offices. The necessary technical coefficients for these sectors would have to be established by special survey. Artle (8) has described an input-output table for Stockholm, Sweden, that includes a variety of sectors not normally displayed in the input-output table. Table 3 shows part of this table.

The Ontario Ministry of Transportation and Communications has used the approach described to estimate the input to manufacturing industries on a county basis by using the 110-sector Canadian input-output model (9). The manufacturing input estimated in this way was compared with the manufacturing input reported in the Annual Census of Manufactures, and good agreement was obtained between the two sets of data. The standard error of estimate was 12.7 percent, and most of the large discrepancies occurred in those counties with low levels of production.

MacDonald (10) has provided a comparison of the observed 1970 inputs to the Ontario brewing industry and compared these with the inputs estimated by using Eq. 4 and the technical coefficients of the 1965 Ontario input-output table. Table 4 gives this comparison for the four input sectors. This table shows that the input magnitudes for the sectors supplying the principal inputs are estimated well by the technique but that nonmetal mining and grain mills sectors are underestimated by the procedure. MacDonald has suggested that in 1970 certain substitute input commodities may have been used which belong to an input-output sector different from the sector origin in the 1965 input-output table. For example, potassium chloride and other salts are substitutes for sodium chloride and these belong to the chemical industries sector.

The spatial linkages for each commodity type may be estimated through the use of the gravity model as originally suggested by Leontief and Strout (3). The form of the gravity model that has been used is

$$t_{ij}^e = p_i^e \frac{a_j^e f_{ij}^e}{\sum_j a_j^e f_{ij}^e} \tag{5}$$

where

t_{ij}^e = the annual production of commodity type e in zone i consumed in zone j and

f_{ij}^e = the influence that transport costs d_{ij}^e have on the spatial patterns of production and consumption of commodity type e.

Black (11) has used the following form of the gravity model impedance function

$$f^e_{ij} = (d^e_{ij})^{-n}$$

and has estimated the magnitude of n for various commodity types in the United States. Table 5 gives some of Black's results.

The approach outlined above has been described in more detail by Hutchinson (6) and used by the Ontario Ministry of Transportation and Communications to estimate inter-regional commodity flows in Ontario (9). This pilot study has demonstrated that the approach is sound and produces meaningful commodity flows.

EXTERNAL-INTERNAL GOODS MOVEMENTS

The framework shown in Figure 2 suggests that the urban implications of intercity goods movements are a consequence of the modal shipping decisions made by the various economic units. It has been suggested previously that these movements may be classified as either direct consignments or consignments shipped via freight terminals. The relative proportions of these two consignment classes are functions of the intercity freight pricing regime that exists externally to the urban area under study. Modal choice decisions are also influenced by certain institutional factors such as the marketing patterns of industries and ownership or other loyalties to specific transport modes. This second group of influences has been labeled as marketing or distribution channel factors (12).

It is recognized generally that the costs of intercity goods movements consist of five principal components: pickup and delivery, terminal handling, line haul, packaging, and ownership. Wallace (13, 14) has conducted a study of the cost components of goods movement in Canada for 1967 conditions. Figure 3 shows a few of the results obtained in this study. Packaging and ownership costs are not included in Figure 3, inasmuch as these vary widely with the commodity type being shipped. The important characteristic to be noted from Figure 3 is the relative unimportance of line-haul costs, except for very long haul lengths.

The net effect of cost characteristics of the type illustrated in Figure 3 on modal shipping decisions is shown in Figure 4. This figure shows the proportion of road transport used for intercity goods consignments as a function of commodity type, haul length, and consignment size for information collected in the 1963 U.S. Census of Transportation. The analysis on which Figure 4 is based (15) sorted the original census data so that only highway and rail goods movements were represented.

The information given in Figure 4 shows that the shifts from road to rail transport with increasing haul length were small for the higher value per-unit-weight goods such as apparel and communications products. The higher cost of packaging involved in moving these goods by rail was probably the most important factor inhibiting the shift to the cheaper line-haul mode. In contrast, the shifts of primary iron and steel products and machinery to rail transport with increasing haul length were fairly dramatic. Figure 4 also shows that most consignments of less than 30,000 lb were shipped by road transport.

Surti and Ebrahimi (15) and Buhl (16) have shown for the transportation census data that there is an inverse relationship between the size of manufacturing plants and the proportion of road transport used for outbound shipments from these plants. This observation reflects the fact that many large plants have widespread market areas, ship large consignments to these distant markets, and in many cases have direct access to rail facilities.

Wood (17) provided some limited evidence on the size of consignments to and from a 1-mile square area of Brooklyn, New York. The average weight of consignments to the New York City region was 177 lb for inbound shipments and 236 lb for outbound shipments. In contrast, external-internal consignments averaged 13,429 lb for inbound shipments and 23,833 lb for outbound shipments.

Observations such as these suggest that modal freight shipping decisions cannot be predicted simply from a knowledge of zonal aggregate commodity productions and consumptions. For many commodity types it would appear that an understanding of the characteristics of individual economic units is required in order to make modal choice decisions. A number of investigators (18, 19, 20, 21) have attempted to construct

Table 5. Gravity model exponents for various commodity types.

Shipper Group	Exponent
Meat and dairy products	2.625
Canned and frozen foods	2.825
Candy, beverages, tobacco products	1.975
Textile mill and leather products	0.850
Apparel and related products	1.025
Paper and allied products	1.500
Basic chemicals, plastics, and synthetics	1.675
Drugs, paints, and other chemical products	2.450
Petroleum and coal products	0.275
Rubber and plastics products	0.950
Lumber and wood products	0.675
Furniture and fixtures	0.975
Stone, clay, and glass products	5.325
Primary iron and steel products	0.950
Primary nonferrous metal products	1.100
Fabricated metal products	1.875
Metal cans, miscellaneous fabricated metal products	1.525
Nonelectrical industrial machinery	0.250
Machinery	0.600
Communications products and equipment	0.425
Electrical products and supplies	0.375
Motor vehicles and equipment	0.500
Transportation equipment	0.400
Instruments, photographic equipment, watches	0.500

Figure 3. Components of haulage charges in Canada, 1967.

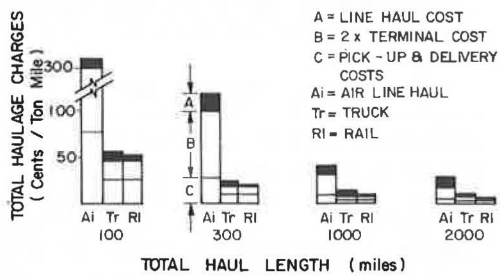


Figure 4. Road transport share versus haul length, consignment size, and commodity type.

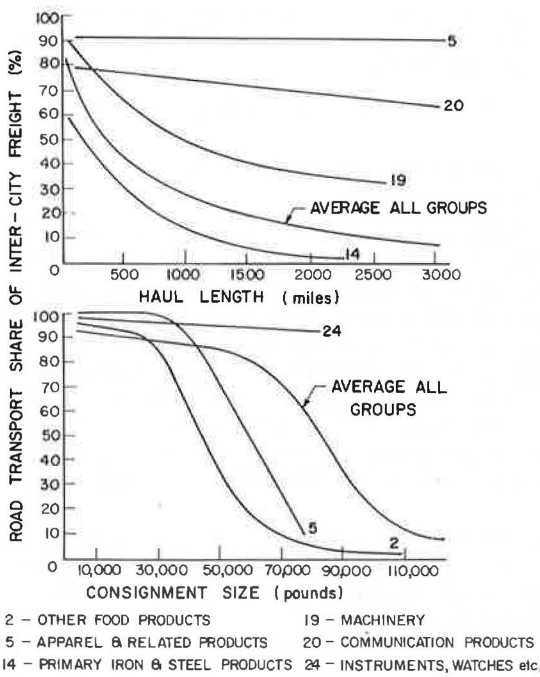


Table 6. Simple correlation matrix of production and truck trip variables.

Production Variables	Truck Productions	Truck Attractions
Male manufacturing employment	0.183	0.286
Female manufacturing employment	0.068	0.038
Total employment	0.206	0.274
Raw material input	0.233	0.327
Goods for resale as such	0.023	0.020
Annual sales of goods	0.137	0.273

micromodels of individual modal shipping decisions. Some of these methods are based on a total transport cost approach using information of the type shown in Figure 3. There are difficulties with these cost-based approaches, for with many plants freight rates are negotiated on an individual basis and do not necessarily relate systematically to average transport costs.

The evidence demonstrates that an important input to the study of urban goods movements demands is the national transport policies governing intercity freight movements. In Canada, rail and air freight terminal locations are regulated by the government, and the specific locations of these terminals significantly influence pickup and delivery costs. The government also regulates intercity rail and air services and interprovincial trucking. Changes in terminal locations, pricing, and other regulatory policies can have an important influence on urban goods movement demands.

Virtually all of the internal interindustry movements of goods are carried by truck. Little empirical evidence is available on the nature of these movements. The framework shown in Figure 2 suggests that these goods movement demands may be estimated during the calculation of the production and consumption linkages by commodity type. Empirical evidence must be obtained before suitable hypotheses governing interindustry movements within urban areas can be advanced.

URBAN TRUCK MOVEMENTS

A basic premise of the forecasting framework presented in Figure 2 is that a knowledge of direct consignments, consignments via terminals, and internal interindustry movements will yield estimates of the demands for urban trucking and through this an estimate of urban truck movements.

A large number of factors influence the relationship between commodity productions and consumptions and urban truck movements. For example, Wood (17) has suggested that major urban truck movements may be classified as

1. Single shipment loads that tend to be large and that often take up the entire capacity of a truck,
2. Single-origin shipments with multiple deliveries and vice versa, and
3. Simultaneous pickup and delivery at each stop.

Wood noted that for the tri-state region in 1963 single shipment loads accounted for 21 percent of the truck vehicle-miles but almost 70 percent of the tonnage of goods moved. Multiple-stop loads generated about 55 percent of the truck vehicle-miles and about 30 percent of the tonnage. Smaller trucks accounted for about 90 percent of the truck trips observed in the region. These observations would suggest that the relationship between the annual productions and consumptions and truck movements may not be a simple one.

Reference has been made to a study of manufacturing industry-generated truck movements in metropolitan Toronto. One-day inventories of truck movements were obtained at each manufacturing firm. The objective of this study was to develop daily truck trip generation equations in terms of the same variables used to describe the properties of various economic limits.

Table 6 gives the simple correlation matrix for the various economic variables used in Eqs. 1, 2, and 3 and truck trip productions and attractions. This table shows that none of the production variables is strongly related to daily truck trip productions or attractions. It is interesting to note this in spite of the fact that the production variables have been shown earlier to be strongly related to the annual sales of goods.

It has been observed in a number of studies that manufacturing industries with a high demand for trucking tend to have their own truck fleets. Data on private trucks owned by manufacturing industries were collected, and Table 7 gives the simple correlation matrix for trucks by type and the productions and attractions. The strong relationships between total trucks owned and truck productions and attractions should be noted. It should also be noted from Table 7 that 2-axle, dual-tired trucks and trucks with 4 or more axles are the most important components of private truck fleets. All of the subsequent regression analyses were performed in terms of either total trucks, 2-axle trucks, or 3 or more axle trucks. Table 8 gives the proportions of trips by various

Table 7. Simple correlation matrix of private trucks available and trip productions and attractions.

Private Trucks Available	2	3	4	5	Truck Productions	Truck Attractions
1. Total number	0.396	0.911	0.171	0.432	0.888	0.718
2. 2 axles, single tire		0.155	0.413	0.006	0.385	0.155
3. 2 axles, dual tire			0.038	0.141	0.855	0.660
4. 3 axles				0.024	0.057	0.130
5. 4 axles or more					0.215	0.411

Table 8. Proportions of truck types observed.

	Trip Production		Trip Attraction	
Truck Size	Number	Percent	Number	Percent
2-axle, single-tire	603	24.4	679	32.2
2-axle, dual-tire	1,310	52.8	1,019	48.3
3 axles	173	7.0	124	5.9
4 axles or more	391	15.8	287	13.6
Total	2,477	100.0	2,109	100.0

Table 9. Truck trip generation equations.

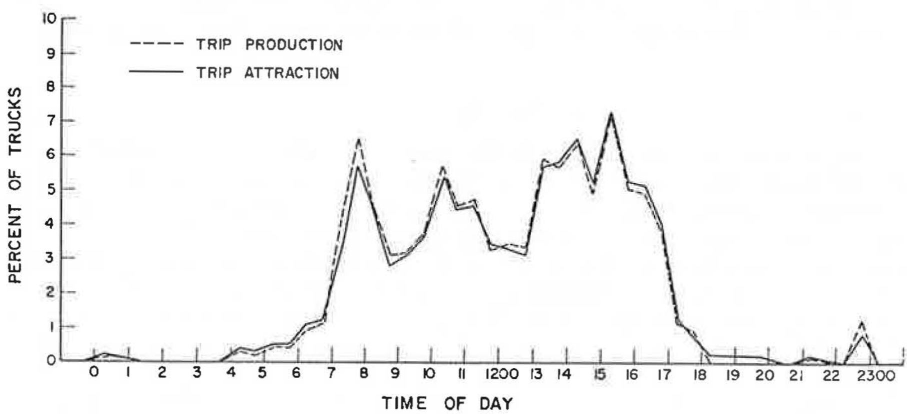
Truck Trip	Equation	R^2
Productions	Daily trips produced = 11.4 + 1.53 (total private trucks owned)	0.807
Attractions	Daily trips attracted = 12.5 + 0.86 (total private trucks owned)	0.532

Table 10. Truck trip generation equations by industry.

Industry Group	Equations
1. Food and beverage	$\log_e YP = 2.62 + 0.33 \log_e$ (private trucks) $R^2 = 0.656$ $YA = 2.24 + 0.10$ (male manuf.) + 0.39 (private trucks) $R^2 = 0.715$
10. Paper and allied products	$\log_e YP = 0.74 + 0.43 \log_e$ (total office emp.) + 0.22 $\log_e$ (private trucks) $R^2 = 0.600$ $YA = 7.03 + 0.07$ (male manuf.) $R^2 = 0.293$
11. Printing, publishing	$\log_e YP = 1.05 + 0.28 \log_e$ (male manuf.) + 0.51 $\log_e$ (private trucks) $R^2 = 0.883$ $\log_e YA = 2.29 + 0.26 \log_e$ (private trucks) $R^2 = 0.418$
14. Machinery	$\log_e YP = 1.11 + 0.32$ (total office emp.) $R^2 = 0.190$ $YA = 4.54 + 0.13$ (total office emp.) + 1.50 (private trucks) $R^2 = 0.751$

Note: YP = daily truck trips produced; YA = daily truck trips attracted.

Figure 5. 24-hour distribution of truck movements for all manufacturing industries.



truck types observed in the study. About 70 to 80 percent of both the productions and attractions were made by 2-axle trucks.

A number of regression analyses were performed in an attempt to relate truck trip productions and attractions to a variety of independent variables, particularly those that had been shown to be related to annual sales of goods. Table 9 gives the equations developed for the Toronto data for all industry types combined. The number of private trucks owned was found to be the variable that best explained the observed variation in truck trip rates, which is simply a confirmation of the observations made in connection with the earlier tables.

There are difficulties in using the equations given in Table 9 for predictive purposes because of the problems of estimating the magnitudes of the independent variables for future times. In an attempt to develop more useful trip generation equations, the survey information was disaggregated into a number of industry groups and the regression equations given in Table 10 were developed. A number of these regression equations are not valid statistically but are the best that could be developed. The number of private trucks owned is still the dominant independent variable. Difficulties still exist in using the equations given in Table 10 for predictive purposes. Valid equations could not be developed in terms of employment variables alone.

This analysis suggests that simple relationships between truck movements and employment or other economic variables are not possible because of the large number of factors influencing trucking demand. Improved equations might have been obtained if truck movements had been observed over the period of a week and the equations developed in terms of average daily truck movements. Available evidence suggests, however, that the improvements in the equations would be marginal. It seems clear that improved techniques for estimating trip productions and trip attractions rely on the development of a more detailed understanding of the distribution logistics of various types of economic units within urban areas.

DAILY TRUCK MOVEMENT PROFILES

The truck trip generation equations described previously are for a 24-hour period. A useful set of information obtained in the Toronto survey was daily time profiles of truck movements.

Figure 5 shows the hourly distribution of truck movements for all manufacturing industries for trip productions and attractions. Trucks involved in the movement of raw materials had two peaks: a major peak at 10:30 a.m. and a minor peak at noon. Trucks involved in the movement of finished products had peaks at 8:00 a.m., 10:30 a.m., and 3:00 p.m., the dominant peak being at 3:00 p.m.

Figure 6 shows a 24-hour time profile of trucks that deliver finished products for each of four truck types. The largest number of 2-axle, single-tired trucks are generated at about 8:00 a.m. The remaining truck types tend to move generally throughout the normal 8:00 a.m. to 3:00 p.m. period with peaks at midmorning and midafternoon.

Figure 7 shows the daily time profiles of trucks involved in the delivery of raw materials. These distributions tend to have the same characteristic shape as those presented in Figure 6 with the exception of a peak at about 8:00 a.m. for 2-axle, single-tired trucks.

CONCLUSIONS

Goods movement demands are created by the economic activities of production and consumption. Each economic unit receives commodity inputs and dispatches commodity outputs. To be useful, urban goods movement forecasting techniques must be developed in terms of fairly simple measures of economic activity, such as employment.

Goods movement demands may be classified into external-internal consignments and internal consignments. External-internal consignments may be subdivided into direct consignments and consignments shipped via freight terminals. The nature and magnitudes of these various goods movement types are a function of the national economic environment.

Studies of manufacturing industries in metropolitan Toronto have shown that annual

Figure 6. 24-hour distribution of truck movements by truck type for finished product deliveries.

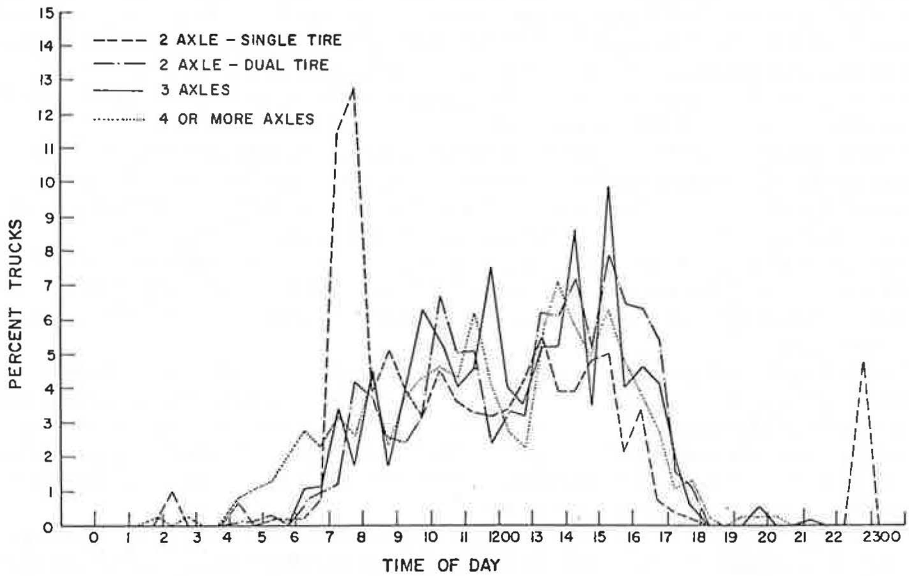
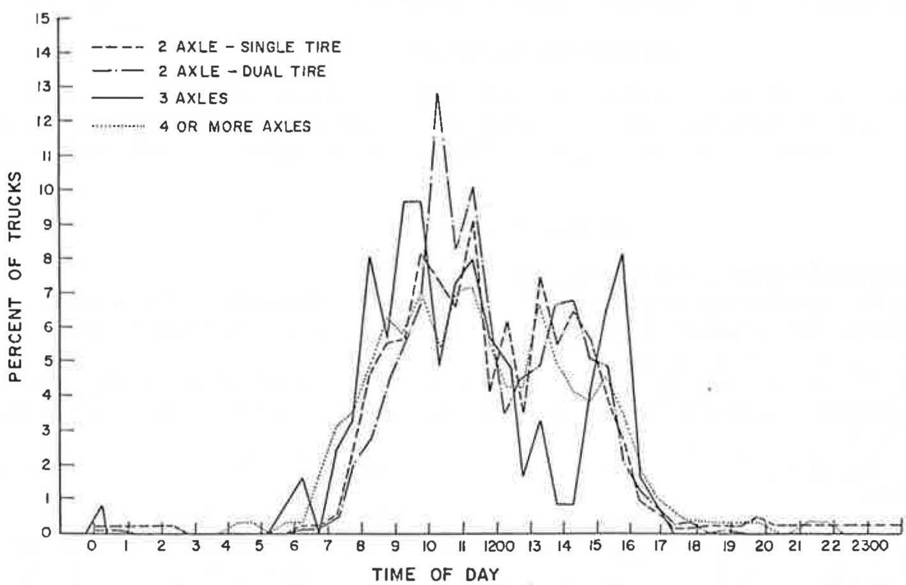


Figure 7. 24-hour distribution of truck movements by truck type for raw material deliveries.



sales of goods may be estimated reasonably well from a knowledge of total employment and the amount of goods received for resale. The manufacturing inputs could not be estimated so reliably by using total employment as the independent variable. An improved method of estimating the inputs to a particular manufacturing plant is the direct requirements matrix of an input-output table along with the annual production output.

Several empirical studies have shown that the spatial linkages of commodities may be estimated by using a gravity model formulation.

The urban implications of external-internal goods movements are a function of the intercity freight modal shipping decisions. These modal shipping decisions are influenced by the intercity freight pricing regime as well as the distributional structures of various industrial organizations. The principal factors influencing these shipping decisions are consignment size, trip length, and commodity type. Available empirical evidence would suggest that freight modal decision cannot be developed simply in terms of zonal aggregate characteristics but should be based on an understanding of the properties of individual economic units.

Studies of urban truck trip generation rates in metropolitan Toronto have demonstrated that these rates are not strongly related to any of the variables that characterize the production levels of the industries. The number of private trucks owned by manufacturing industries was the independent variable that best explained truck trip production and attraction rates. The study showed that 70 to 80 percent of truck trip productions and attractions were made by 2-axle trucks.

The manufacturing industries were classified into a number of groups in an attempt to develop regression equations that contained production variables as the principal independent variables. The number of private trucks owned was still the dominant variable, although some production variables did enter into these equations. Improved techniques for estimating truck trip generation rates depend on better understanding of the distribution logistics of various groups of industries.

ACKNOWLEDGMENTS

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CONSOLIDATION OF URBAN GOODS MOVEMENTS: A CRITICAL ANALYSIS

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This paper investigates the desirability of consolidation terminals as a means to lower the cost and ease the congestion of urban goods movement. A detailed simulation of alternative configurations of pickup and delivery services is used based on a unique set of data obtained from operators of actual consolidation facilities. The alternatives analyzed are no consolidation, the prevailing mode of operation; route consolidation, which eliminates duplication in the pickup and delivery area; and complete consolidation using consolidation terminals. Because of the high costs of handling goods in consolidation terminals, they are shown to be relatively uneconomic. Route consolidation, however, appears to be the most effective solution and offers savings of up to 30 percent. These results were verified by extensive sensitivity analyses, reported in detail, that provide guidelines on the desirability of each form of pickup and delivery service. No new program of consolidation now appears likely to reduce urban congestion or pollution significantly inasmuch as consolidation has already been implemented in many of the industries for which it offers the greatest potential. Consolidation does appear, however, to offer potential for industries that are quite uncoordinated, e.g., the garment trade and the air cargo business.

•THE DEVELOPMENT of consolidation terminals has been frequently advocated by knowledgeable observers, in particular by those in the Tri-State Transportation Commission (10). To examine this proposal, we define the possible forms of consolidation for goods movement and compare their relative effectiveness over the range of possible circumstances. The analysis is validated by detailed data on actual operations of consolidation services in New York City.

The results show that consolidation terminals can be cost-effective, but only for a very limited, although important, form of goods movement. These facilities are especially desirable when great savings in transport cost can be obtained relatively cheaply. This is particularly the case for garbage collection. New York City has already achieved considerable savings in the costs of collecting solid wastes by operating consolidation facilities. In general, however, consolidation terminals seem too expensive to be desirable.

A different form of consolidation does appear desirable for a broad range of situations. This is route consolidation or the coordination of multiple pickups and deliveries by a single shipper, so as to eliminate duplication of travel along common routes. This alternative appears promising, especially for relatively small shipments made to or from many shippers (e.g., parcel service and air cargo). Route consolidation represents an economical solution to many of the problems of urban goods movement.

INTRODUCTION

A consolidation terminal is a facility at which many small shipments are assembled into fewer, larger shipments to permit goods to be shipped by fewer vehicles than would otherwise be possible. This leads to significant reductions in the costs of transport and to savings in fuel. Fewer vehicles also mean less congestion, less noise, less pollution, and generally a more enjoyable environment.

The advantages of consolidation terminals are offset, however, by the large costs associated with their operation. Furthermore, any form of consolidation requires some coordination of the pickup and delivery of goods, which may be impractical because of the conflicting interests of the individual shippers. Without a detailed analysis, such as reported here, it is impossible to know when or whether the disadvantages of consolidation are smaller than the advantages.

This study analyzes alternative forms of consolidation for urban goods movements and attempts to answer the following questions.

1. What kind of consolidation activities are possible?
2. What are the relative economics of these alternatives?
3. How do the economics vary for different types of load and for different distributions of pickup and delivery points?
4. What kinds of environmental benefits does consolidation provide?
5. What types of consolidation, if any, are desirable for which situations?

The immediate objective of this work is to develop guidelines on when and what type of consolidation of urban goods movements should be promoted. In a larger sense, the results have implications for the optimal design of transportation and communication networks of all sorts and constitute an integral part of ongoing work on network systems planning at the M.I.T. Civil Engineering Systems Laboratory (1, 2, 6).

CURRENT PROBLEMS

Most trucking within a large city, such as New York, consists primarily of pickup and delivery (PD) operations. Essentially, all local goods movements are of this sort, and many long-distance shipments have PD components of interurban movement by rail, air, and even truck.

Typically, PD operations involve considerable duplication of effort. Urban goods movements are characterized by a large number of both shippers and carriers. On any day, many different carriers dispatch their trucks to provide similar services to the same shippers or to their neighbors. Either way, the PD vehicles follow each other over approximately the same routes. This duplication is an important cause of inefficiency in urban goods movement.

A second problem of PD operations is that they are typically unable to achieve economies of scale. Although the distance between the pickup and delivery areas in a city is often great, cartage between these points is most usually done by small PD vehicles rather than by larger vehicles that could be more economical over the distance. For example, most shippers in the New York area are 15 miles or so from the container ports or from the cargo center at Kennedy Airport; likewise the garbage disposal sites are far from where the waste is collected. The lack of coordination often forces people to use small PD vehicles for such trips, even though larger vehicles could haul the cargo more cheaply.

Third, PD services operate under restrictions that severely raise costs by degrading productivity. These constraints have to do with the fact that the inputs to the PD operations come in fixed sizes:

1. A truck fleet, once bought, cannot be contracted during off-peak hours and is thus relatively idle during those periods.
2. Trucks have maximum loads and volumes [e.g., 5 tons (4550 kg) and 1,200 ft^3 (34 m^3)]; an operator may waste time because he cannot use his truck to pick up or deliver more shipments.
3. Drivers and crews have fixed workdays, typically 8 hours per day, which, converse to the above, may not give them enough time to fill up a truck.

The net effect of all these constraints is to lower the load factors of the trucks and to raise unit costs exponentially.

The problem of shipping goods from the New York garment center to La Guardia illustrates the effect of these constraints. The travel time between the two points is about 1 hour each way, leaving the driver at most 6 hours for pickups and deliveries. At 15 minutes or more per stop, he may not have enough time to assemble a full load; the truck then is used inefficiently. This bad situation worsens considerably if the terminus (or disposal point, for garbage) is farther away. For deliveries from the garment center to Kennedy Airport, the round trip may take more than 3 hours, which reduces effective PD time by about 20 percent. From a mathematical point of view, the shadow prices on these constraints may be extremely high. This was demonstrated by de Neufville et al. who performed detailed calculations for actual cases (3).

Finally, all urban goods movements are subject to strong variations in demand, for they force the carriers to maintain substantial reserve capacity to handle peak traffic, which thus reduces the overall productivity of the fleet. Traffic peaks are also surprisingly large as demonstrated by detailed analysis of actual waybills obtained from a PD operator in New York (3). There are strong imbalances in traffic both over time, with ±30 percent variation in a week let alone over a month or a year, and in direction, with flow in one direction being 100 percent greater than in the other. Such imbalances in flow inevitably lead to low average truck use (load factors ≈30 percent).

ALTERNATIVE NETWORK CONFIGURATIONS

The three basic alternatives for organizing PD operations are

1. No consolidation, similar to what prevails currently,
2. Route consolidation, and
3. Complete consolidation.

Route consolidation, a term introduced here, only addresses the problem of duplication. It represents an attempt to achieve maximum savings at minimum cost. Complete consolidation introduces intermediate (or consolidation) terminals into the network and thus leads to economies of scale and lessens the effect of the constraints. A basic question is whether the advantages are worth the extra costs of the consolidation terminal, which may be considerable.

The elements of the PD system need to be defined before we can illustrate the alternatives precisely. These elements are as follows:

1. Shippers, the individual merchants or households who originate or finally receive a shipment (these are likely to be scattered all over an urban area);
2. PD operators, the several outfits that carry shipments from the shippers to a main terminal within the metropolitan area;
3. The main terminal, which is either a gateway to the city for the long-distance portions of a trip (i.e., an airport or a container port) or the end of a trip (i.e., a garbage dump or a manufacturing plant); and
4. Carriers, such as airlines, who transport the shipments long distances to and from the city.

A PD system thus always involves shippers, operators, and main terminals; it may or may not include carriers. With these definitions in mind, the three alternative configurations are described below.

No Consolidation

In this system, competing PD operators serve shippers independently. This option is illustrated in Figure 1, which shows a situation similar to that faced by the airlines delivering cargo to Manhattan or, in reverse, by garment manufacturers sending their goods to Kennedy Airport. Each individual operator probably functions as efficiently as he can in this situation, but it is quite likely that the service for the entire system is inefficient because of extensive duplication.

This is the simplest alternative to manage because no special cooperation is necessary among either the shippers, operators, or carriers. Handling charges may also be expected to be relatively low because shipments are only loaded and unloaded once and there is no need for special sorting. An attractive feature of this arrangement from the shipper's point of view is that he has a choice of PD operators; he can thus expect the competitive element to keep them on their toes.

But no consolidation may be expensive. Individual operators will have their customers spread over a wide area, and their trucks will have to travel long distances in relation to the number of shippers they serve. Because of the large amount of time spent traveling, a driver will be able to make relatively few stops in a day. The resultant low truck use must inevitably lead to higher unit costs.

Route Consolidation

Route consolidation eliminates duplication in the PD area; all shippers in a zone are served by a single truck (Fig. 2). This kind of operation is typical of garbage collection services (which rarely have to worry about a multitude of different carriers and thus have little motivation for competitive, redundant services in an area) and freight forwarders.

The principal advantage of route consolidation is that, by reducing the number of miles that must be driven and the distances between consecutive stops, productivity of the drivers and the use of the trucks are increased. This, of course, reduces the unit costs of PD operations. Further, less driving means less air pollution and less congestion on the streets.

Another advantage of this alternative, and actually of all forms of consolidation, is that it reduces the variability in the level of flows, and this lowers costs. Because the peaks of traffic from some shippers must inevitably overlap with the off peaks of others, the relative variation of a collective activity will be less than the variation of the individual shippers. A reduction in the size of the peaks means that the PD operation needs less reserve capacity to handle the peak flows and can consequently raise average truck use and lower unit costs.

A high degree of cooperation between carrier and PD operator is essential for this type of operation. By definition, PD operators now work for several carriers, and trucks must make several stops at the main terminal. Conversely, each carrier must sort its shipments geographically so that they can be picked up by the appropriate PD vehicle. This may be both expensive and time-consuming, especially when the number of participating carriers is large. Route consolidation may then be desirable for small groups of carriers rather than simultaneously for all carriers at a terminal.

Complete Consolidation

The key feature of this alternative is a consolidation terminal placed between the main terminal and the PD area. This intermediate node permits not only consolidation of routes, as above, but also consolidation of traffic from each zone of the PD area. Consolidation terminals are relatively rare, but several do exist in New York City: National New York Packing in the garment center, Rydair in Long Island City for air cargo, and several facilities for garbage collection. For best effect, the consolidation terminal should be placed near the PD area (Fig. 3).

Use of consolidation terminals leads to savings in transport costs and raises driver productivity. A consolidation terminal is most obviously a facility for aggregating the loads of the PD trucks, generally onto larger, more efficient vehicles (or vice versa). At a minimum, one can operate with full vehicles between the consolidation and main terminals; more often one can achieve some economies of scale by using larger vehicles. These savings may sometimes be quite significant. Garbage collection, for example, requires a driver plus two or three loaders in the pickup operations, but only a driver for the haul to the dump. Use of a transfer point, at which the extra men can be left off, cuts transport costs in half. In most cases, however, the savings in transport costs turn out to be of marginal importance.

The more important effect of consolidation terminals appears to be increases in driver productivity and thus decreases in unit costs. To the extent that they are close to the PD area, consolidation terminals reduce the time the PD vehicles must spend driving and increase the time that can be spent in picking up shipments. This effect is

Figure 1. General no-consolidation PD operations.

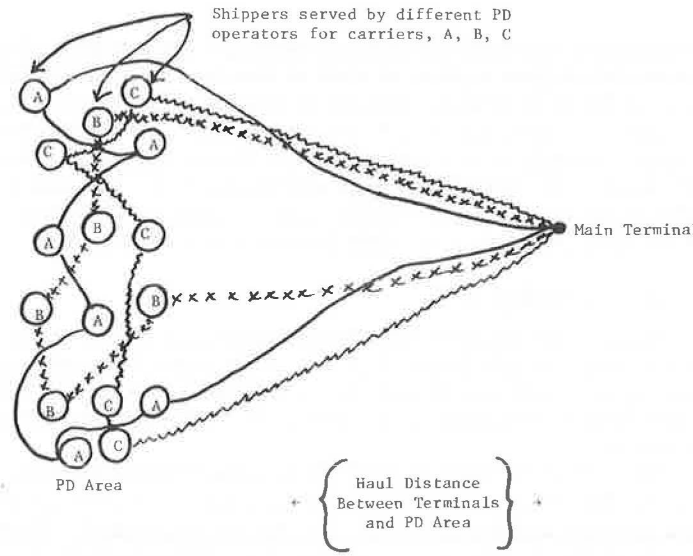


Figure 2. Route consolidation.

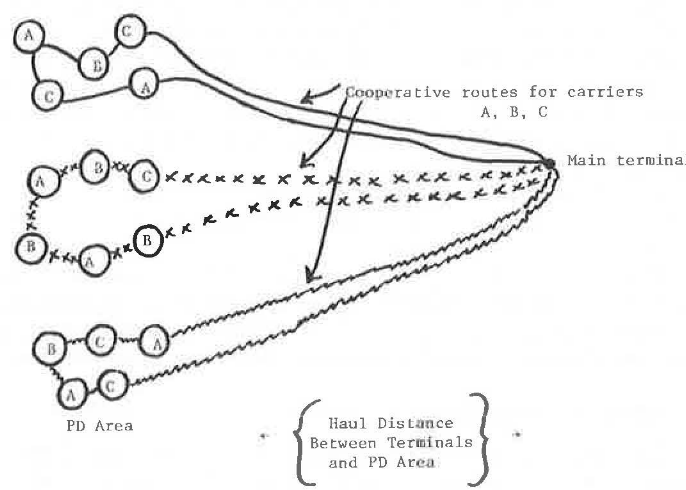
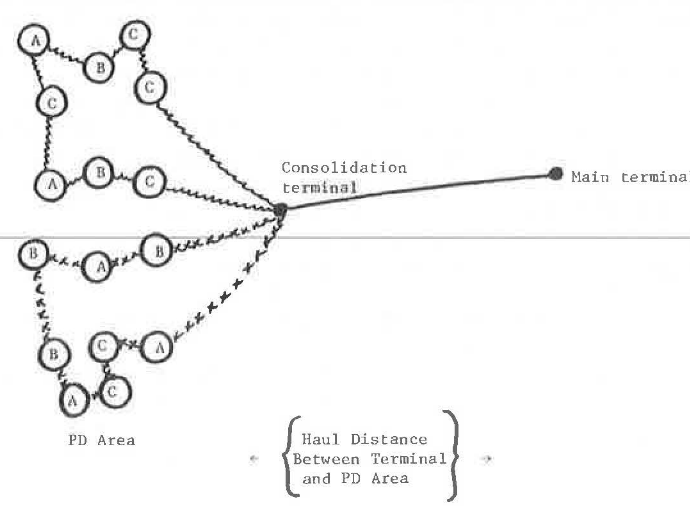


Figure 3. Complete consolidation.



important both when the shipments are small and the productivity is constrained by the time that can be spent loading the truck and when shipments are large and the truck fills up quickly and could do several round trips a day.

Balancing these advantages, however, are the costs of handling shipments at the consolidation terminal, as well as the rent and upkeep of the facility itself. These may be very high. For small shipments, costs of $1 a package or $80/ton ($0.09/kg) are quite common (1, 3, 5). These costs do fall to about $10/ton ($11/Mg) for packages of about 500 lbm (230 kg) and to less than $1/ton ($1.10/Mg) for bulk shipments of several tons (7). But the consolidation or transfer costs would generally be quite significant for most shipments of urban goods.

EVALUATION OF ALTERNATIVES

Procedure

To compare the alternative modes of PD operations, we developed a simple computer model. This is basically an unpretentious device for keeping track of and adding up all the costs associated with any realistic description of a situation. The model is a deterministic simulation capable of handling the pervasive nonlinearities and integer nature of the problem. It calculates total costs, the necessary number of trucks, and total truck-miles per day to serve any specified distribution of shipments in any particular area (3). If the appropriate data are supplied, the model can evaluate any number of alternative configurations, the effect of different locations for the terminals and shippers, different levels and distributions of traffic, and different kinds of shipments. The model can thus be used to compare the alternatives and to select the best solution for any situation.

The procedure used was straightforward. We selected a particular situation as a base against which we would measure all other alternatives. In practice this was an actual PD operation in New York City for which we had abundant data. We then calculated the effectiveness of alternative configurations for this situation. Finally, we carried out extensive sensitivity analysis to determine when any of the alternatives might become more desirable (4).

Data

Extensive, detailed information is required for an effective evaluation of alternative modes of PD operation. Because of the complex interaction of the constraints on these operations, any gross analysis that overlooks these subtleties will be erroneous. Because only aggregated data were previously available (11), it had not been possible to evaluate the desirability of consolidation terminals. We were most fortunate, however, to be able to obtain the kind of data necessary.

We were able to obtain unique information concerning the distribution of demands for PD services from the Rydair Company. They generously gave us complete access to their waybills, which specify which shipper was served by which truck, the weight and number of pieces in the shipment, the carrier serviced, the date, and so on. These data enabled us to determine fluctuations in demand over time and from place to place. We were also able to reconstruct in detail how the PD trucks operated, how long they took to make each stop, and what routes they actually traveled. All this empirical evidence was verified by M.I.T. personnel who rode with the trucks. These data are described more fully elsewhere (3) and are available for study from M.I.T. Although the data cover only a small portion of urban goods movements in the city, it is believed that they are generally representative.

Data on the costs of transportation and handling were also obtained from Rydair. These were supplemented by public sources and private interviews with local truckers. Detailed information about traffic speeds was fortunately available from the 1968 Kennedy Airport access study (8), which determined, by actually driving the routes, the peak and off-peak travel times on hundreds of route segments in the city.

The Model

The model initially computes the number of packages each driver to a particular area can handle. First, the productive pickup and delivery times for a truck in a given zone are calculated based on the driver's shift (normally 8 hours) and the driving time between the terminal and the PD area. Next, the average time per stop is estimated for each truck based on the travel speed, the average distance between stops, and the time a truck requires to serve a shipper. The actual number of packages that can be handled is then determined by examining the limits on the weight and volume of the truck compared with the package size, as well as on the driver's time. The most binding of these considerations determines how many stops can be made in a day in that zone by one truck.

After these determinations, the model calculates the total number of trucks required to service a market. Handling, transport, and other costs are then estimated and added to the costs of the trucks and drivers to determine operating costs of the system being considered. Total costs are then found by adding in average overhead expenses.

Additionally, the model derives several other measures of effectiveness to reflect the impact of the alternative systems on the environment. Specifically, the number of trucks required and the number of truck-miles driven lead to an assessment of the contribution of the PD operation to traffic congestion and air and noise pollution.

Base of Comparison

As a base for comparing alternatives we selected an existing situation in New York: the consolidation terminal and PD operations of the Rydair Company. Using an actual operation enabled us to validate the model; we checked to see whether it could replicate the actual operations (it did).

The Rydair Company handles air cargo for some 22 domestic and international carriers. Its consolidation terminal is in Long Island City relatively close to its PD area in downtown Manhattan. It carries shipments between this point and both Kennedy and La Guardia Airports in large, 45-ft (14-m) tractor trailers and performs PD services with smaller 25-ft (8-m) single-unit trucks. All cargo is unloaded, sorted, and reloaded at the consolidation center. Rydair handles about 31 tons (28 Mg) of cargo and makes about 300 PD stops a day in Manhattan alone. Although it accounts for only a small fraction of all the urban goods movements in the city, it is comparable in size to other consolidation operations, e.g., National New York Packing in the garment center.

RESULTS

The analysis confirms that consolidation can lead to dramatic improvements in truck use but shows that complete consolidation with consolidation terminals may be economically inefficient. For many circumstances route consolidation may be the most desirable configuration for urban goods networks.

Increase in Utilization

Consolidation can easily cut the total truck-miles by four-fifths, as shown in Figure 4. This translates immediately into greater truck use. For this case, the average load per vehicle in the system went from 1-2 tons (900-1800 kg) per truck for no consolidation to 3-4 tons (2700-3600 kg) per truck for complete consolidation. Systemwide load factors correspondingly went from 22 to 68 percent. This is as expected.

But there is a surprise. Although route consolidation is explicitly designed to reduce truck-miles in the PD area, it achieves most of the reductions (in this case 70 to 80 percent) in the haul between the PD area and the terminal. As a further anomaly, complete consolidation, which is not especially intended to reduce mileage in the PD areas, is actually as effective in doing that as route consolidation, which is explicitly designed for that purpose.

These findings illustrate the kind of complexities caused by the interaction of several constraints on the operations. In this instance, these results are apparently a consequence of the fact that, as for most PD operations, the shipments are small. The driver of the truck thus comes to the end of his shift before his truck is full. In this situation, savings in time permit the drivers to make additional stops, and this in turn reduces the number of trucks required to serve a given number of stops. Route consolidation, which is developed to reduce mileage in the PD area, actually saves considerable time by doing this because traffic is slow in downtown areas. These savings in time translate into fewer trucks going to the main terminal and considerable reduction in line-haul mileage. Conversely, the complete consolidation option, which is designed to reduce line-haul mileage, saves considerable time for the drivers in the PD area because they need not travel to the main terminal, and this in turn leads to more stops per truck and less mileage in the PD area. If nothing else, these results indicate that a crude aggregate analysis of consolidation would fail to indicate what actually is happening.

These results also suggest an important policy implication: Consolidation of trucking operations does not appear to be a useful tool for reducing pollution in the downtown areas. Indeed, air and noise pollution are both related to mileage. As indicated by Figure 4, PD operations may not involve much downtown mileage so that, even when consolidation leads to relatively significant savings in the PD area, these reductions are actually quite small on the absolute basis.

Reduction in Costs

Although complete consolidation results in the most significant improvements in truck use and driver productivity, it is generally not the most economical solution because of the significant costs of operating a consolidation terminal. As shown in Figure 5, the costs of handling the goods at a consolidation terminal can easily equal the costs of the truck operations and thus wipe out the potential advantage of complete consolidation. This conclusion is naturally sensitive to the costs of consolidation; when it is very inexpensive, as it can be for solid waste, the complete consolidation alternative may be desirable (7).

In a number of special cases, the advantages of complete consolidation can be obtained without paying for the terminal or for extra handling. These are situations, as for garbage collection, when the crews required for the pickups are larger than those necessary for the haul. It may then pay to establish transfer points where one crew leaves off and the other picks up. Transfer points of this sort have been successfully established by the New York City Department of Sanitation.

With reference to the particular case examined, we can see that the decision to establish the consolidation facility did lead to less expensive operations for the airlines in New York City. But the analysis suggests that a 30 percent increase could have been achieved by simply consolidating their PD routes.

The results shown in Figures 4 and 5 are not, incidentally, sensitive to the location of the consolidation terminal, provided it is reasonably near the PD area. It would not be cheaper to locate the facility in Manhattan, for example, and in particular not at the Chelsea docks, a site that has been repeatedly proposed. That site furthermore suffers from the disadvantage of being on the opposite side of the PD area from the main terminals for air cargo (i.e., Kennedy and La Guardia Airports) and thus requires significantly more trucks and higher expenses.

SENSITIVITY ANALYSIS

The relative desirability of the alternatives naturally depends on the exact nature of the situation. We determined precisely when consolidation might be effective by using the model to calculate the relative costs of the alternatives for a range of possible situations. The results give us some guidelines for deciding what networks to use for urban goods movements.

The sensitivity of results to changes in the environment was examined by changing only one variable at a time. This procedure helps isolate the effects of different variables. It also lets us compare all situations with the same base. It should be carefully noted, however, that because an alternative is desirable when a particular variable is

Figure 4. Reduction in truck-miles due to consolidation.

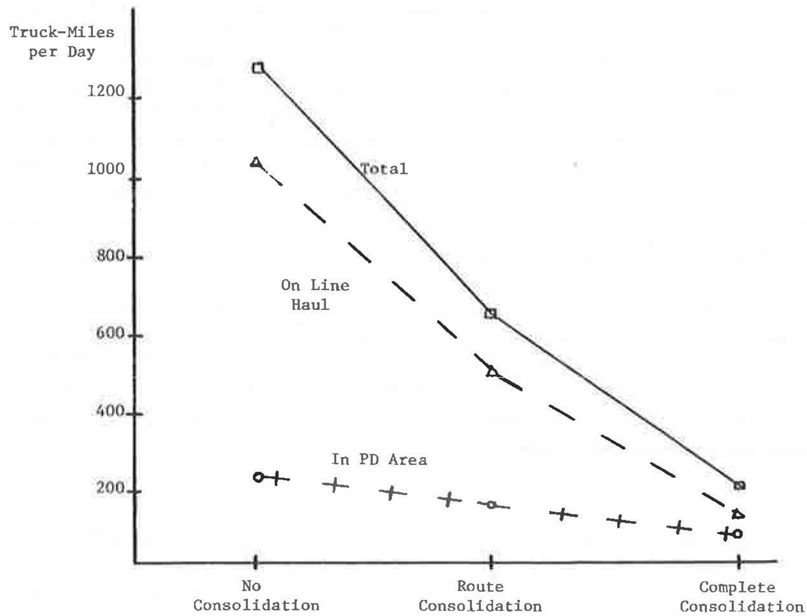
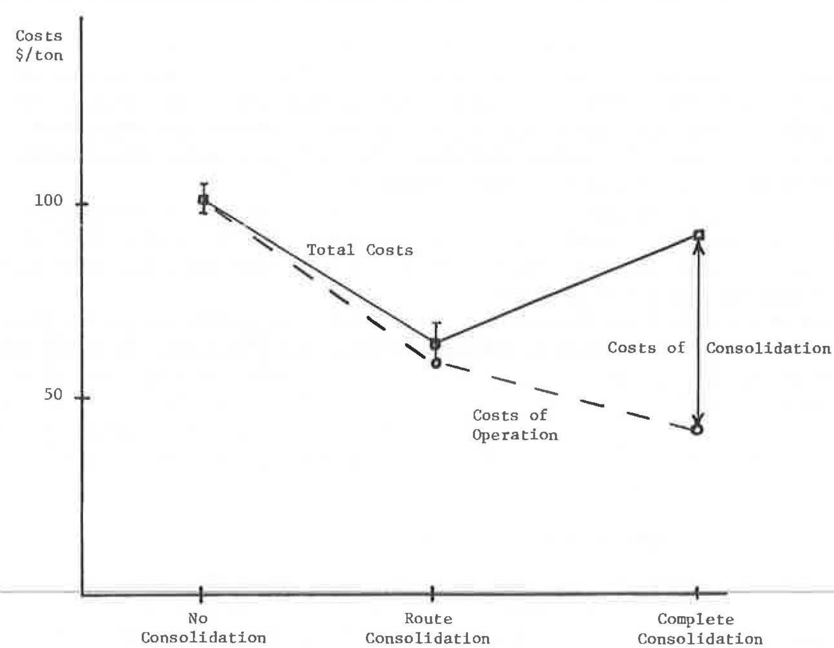


Figure 5. Reduction in cost due to consolidation.



at a given level does not mean that it is desirable whenever that level occurs; changes in other variables could counterbalance this effect.

Effect of Consolidation Costs

Anything that reduces the cost of the consolidation facility tends to make complete consolidation more desirable. This is obvious from Figure 5. Available data indicate that handling costs can be quite low for bulk materials but are almost certain to remain high for the small packages that are characteristic of urban goods movements. Worse, analysis of existing cargo centers indicates that they have strong diseconomies of scale even when automation is introduced (1).

Effect of Haul Costs

Consolidation terminals are more desirable when significant economies of scale can be achieved on the line haul between the PD area and the main terminal, but this effect is actually marginal. As shown in Figures 4 and 5, the line haul accounts for only about half of all transport costs, and these are only half of the total costs of complete consolidation. Even the greatest economies of scale in transport would not, by themselves, reduce total costs significantly.

Effect of Haul Distance

Consolidation terminals and transfer stations are more desirable when the main terminals are farther from the PD area. As this distance increases, the costs of the no-consolidation and route consolidation alternatives actually rise rapidly (Fig. 6). This is because increases in the time required to travel over the line haul squeeze the time available to the driver in the PD area, causing dramatic decreases in his productivity and truck use.

Effect of Shipment Size

Consolidation terminals and transfer stations are also relatively more desirable for larger shipments. As before, the costs of the no-consolidation and route consolidation alternatives rise rapidly (Fig. 7), but in this case the cause is different. What now happens is that, after the size of the packages reaches a certain point, the size of the PD truck replaces the driver's time as the binding constraint. We then find that the PD vehicles are forced to make two or more round trips a day; this is, for example, typical of garbage collection. The alternatives requiring that PD vehicles travel all the way from the PD area to the main terminal are then increasingly at a disadvantage. This phenomenon is another reason why consolidation facilities tend to make sense for garbage collection.

Effect of the Number of Carriers

The relative advantage of consolidation increases with the number of participating carriers, all else being equal. Conversely, if there are too few participants, the proportional share of the overhead for cooperation becomes too large for each carrier, and consolidation becomes uneconomic (Fig. 8). Route consolidation is generally the preferred solution although complete consolidation may be preferable when there are enough carriers. It is interesting to note that the United Parcel Service, which does business with many shippers, moves all its cargo according to the complete consolidation scheme on a national scale.

CONCLUSIONS

There are basically three ways to configure a network for the pickup and delivery of urban goods:

1. No consolidation,
2. Route consolidation, and
3. Complete consolidation with a consolidation terminal.

Figure 6. Total costs of PD alternatives as a function of the haul distance.

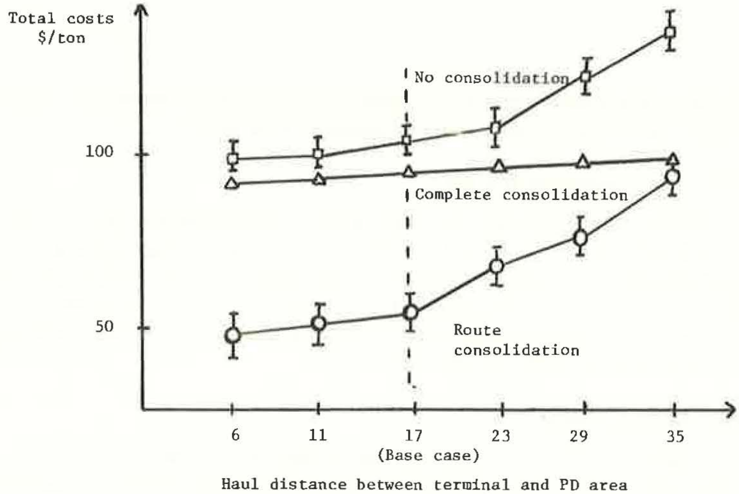


Figure 7. Total costs of PD alternatives as a function of the average shipment size.

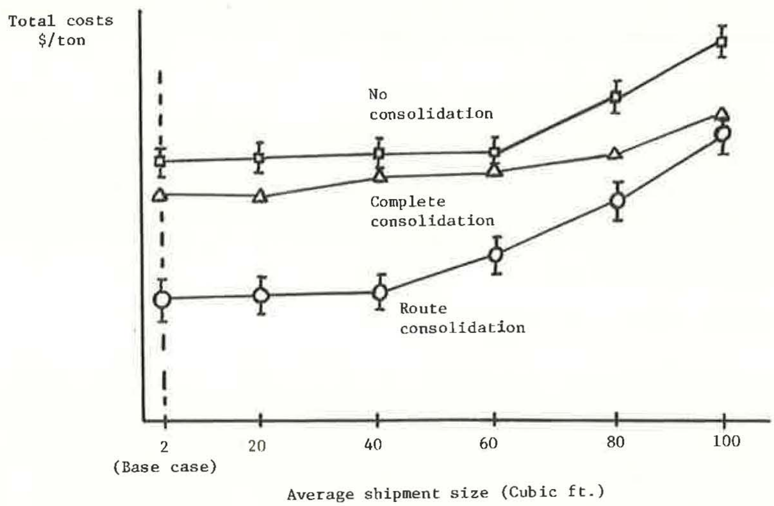
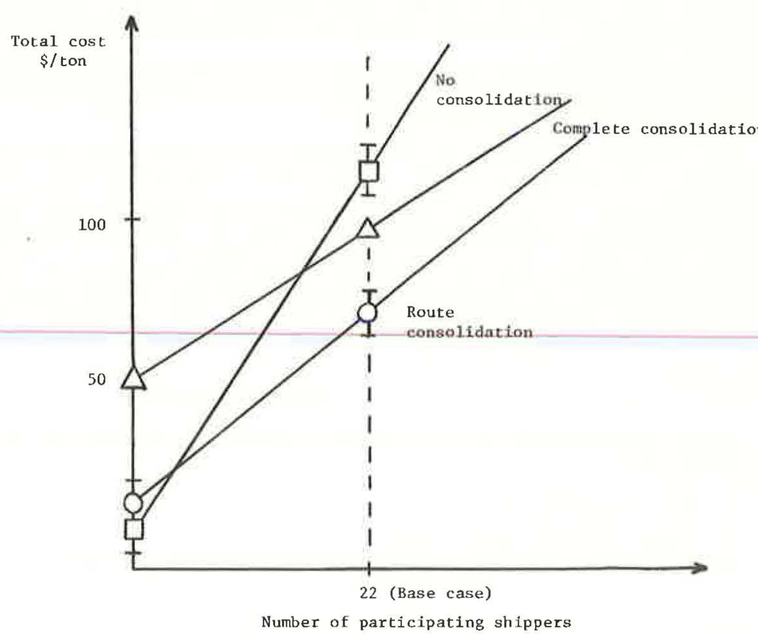


Figure 8. Total costs of PD alternatives as a function of the number of participating shippers.



Route consolidation appears to be generally the best solution.

Consolidation terminals are at a severe disadvantage because of the high costs of handling shipments; they seem to be economical only when these costs can be made very low, when shipments are very large, or when the distance from the PD area to the main terminal is great. Consolidation terminals are thus frequently desirable for garbage collection. They may also be essential for airports located very far from their cities (Stewart Field for New York or Maplin Sands for London). But consolidation terminals do not seem especially attractive for the broad range of problems in urban goods movement.

Consolidation, especially route consolidation, is most advantageous when

1. Consolidation costs and haul costs are low,
2. Haul distances are long,
3. Shipments are large, and
4. There are many carriers to be served.

It would be desirable to encourage consolidation where these conditions are met and where cooperative handling of goods does not already exist. Promising candidates for consolidation are the garment trade and the air cargo business.

These results imply that we cannot expect that new consolidation programs will do a great deal to alleviate current problems in urban transportation. Route consolidation, the best alternative, is already widely practiced for deliveries of mail, newspapers, groceries, and more. These activities would not be affected by a consolidation program. Many activities are furthermore totally unsuited for consolidation. Repair vehicles of all sorts should be excluded from consideration; they are not so much delivery vehicles as mobile repair shops. In short, programs of consolidation of urban goods movements are unlikely to make a real dent in vehicular congestion and pollution in the city.

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FORECASTING URBAN TRUCK TRIPS IN THE UNITED KINGDOM

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In the light of recent circumstances, the paper considers the bases of forecasts of urban truck activity made by transportation studies in the United Kingdom during the 1960s. Particular stress is placed on the importance of control totals, which derive from estimates of national truck activity. Their development appears to have ignored certain trends in the economy and, more specifically, significant changes in the productivity of the truck industry during the last few years. The opinion is proffered that the separate estimates made of zonal truck activity in transportation studies (estimates that are subject to the constraint imposed by the control totals) are characterized by poor statistical analyses. There is evidence that the basic assumptions of linear regression, the preferred method of analysis, are frequently ignored. In conclusion, it is suggested that more attention should be given to the development of adequate control totals and to methods of analysis that consider nonlinearities in zonal truck data.

•IN THE LAST FEW YEARS, the movement of freight in urban areas has become an important transport planning issue in the United Kingdom. There are a number of reasons for this, including the current emphasis on traffic restraint in urban areas, environmental factors, and the stress now placed on the economic appraisal of transport plans. Trucks are less responsive than automobiles to restraint measures; they are seen as environmental villains (currently an emotive issue in the United Kingdom), and the high values of time and cost of operating trucks add to their economic significance. For these and other reasons it is arguable that, in urban areas, freight forecasting is now of more importance than modeling person movements.

The approach in British transportation studies to forecasting urban truck movements has been, in essence, to adopt the fundamentals of the paradigm used for the modeling of person movements. This paradigm traditionally revolves around four separate but interrelated stages of trip generation, distribution, modal split, and assignment. In an urban context, the issue of freight modal split is of little importance, whereas the distribution and assignment stages present no fundamental problems of modeling peculiar to trucks. Although consideration in some studies of these two latter aspects has been rather elementary, this generally signifies a lack of interest and effort rather than profound difficulties of a conceptual kind.

It is when we consider the trip end stage, however, that the methodological contrast with person movement is most apparent and the impact on the final forecast most significant. It is, therefore, largely with this crucial stage, of estimating trip ends, that this paper is concerned.

CONTROL TOTALS

There are two particular procedures that constitute the forecasting of trip ends. First is the prediction of a local control total relating to the overall freight activity in the area studied, and the second is the calculation of movement at the zone level. The independently determined control is used subsequently to constrain the estimates of freight activity derived from the (zonal) trip end model. It is used as a basis for a scaling factor, and its importance can be judged from the fact that in one major transportation study adjustments applied to zonal trips, to match their overall total with the control, alone accounted for 80 percent of the growth in trip end volumes.

The reason for significance of the control is that time-dependent influences on trip generation, e.g., changing vehicle technology, are not as a rule explained by variables used in the trip end model per se. These latter variables traditionally summarize land use characteristics and, therefore, tend to take account only of land use changes. Not only is their specification weak for true forecasting, but they do not allow various policy options, such as restriction on hours of delivery and on vehicle size, to be considered in detail. As a consequence, the control can be a vital means for overcoming these conceptual problems. Indeed, it is the only way some fundamental policy issues can be examined at the present time.

The usual basis of the control is a forecast of the national vehicle stock. It is then assumed that local trips will increase proportionally. The presumption therefore is that the local and national economies will have similar rates of growth and that trips per vehicle will remain constant.

One frequently used method of developing the national forecast has been to extrapolate recent trends in truck registration. However, trends in the United Kingdom since the mid-1960s have been contrary to the established trends of earlier years. Quite apart from the paradoxical situation of projecting supply instead of demand, this reversal serves to warn against the use of such facile methods (Table 1).

An alternative to such simple extrapolation of an overall trend is to develop a quasi demand-supply relationship. In essence the basis of this approach is

$$\left(\frac{\Delta \text{ total ton-miles by highway}}{\Delta \text{ ton-miles per average vehicle}}\right) = \Delta \text{ vehicle stock}$$

where Δ represents the change.

In this approach the demand factors supposedly operate in the numerator and the supply aspects in the denominator. The usual practice here is to treat these two aspects as though they were totally independent of each other. Nevertheless, in a true econometric model the demand and supply conditions are very much interdependent. Demand is partly a function of the truck industry's supply cost. New methods of operation, or new transport facilities that reduce these costs, stimulate demand by the substitution of more transport-intensive factors for less transport-intensive factors in production and by broadening market areas for the final products. This suggests that a proper approach to the issue as a whole would be to use a more general approach, perhaps within the context of input-output analysis. However, for the moment we shall adopt a partial (and traditional) view and consider the demand and supply conditions separately. But, as we shall see, there are indications that significant interactions do exist even within the moderate forecasting period that characterizes contemporary transport studies.

TRENDS IN DEMAND

In the past 2 or 3 years one or two studies have been conducted in the United Kingdom that have analyzed the statistical relationship between the annual growth of the U.K. economy and the annual volume of inland freight transport (1, 2). A feature of these studies has been, on the basis of their poor statistical correlations, their limited success at fully explaining the situation on a year-by-year basis. Presumably this weak relationship is partly due to the fact that, because the economy expands and contracts at different times, different industries with differing transport inputs are affected. Whether some form of lagged time series analysis would improve the results remains an unexplored research field. Meanwhile, the argument has been that "there is no reason to doubt the established long-term relationship between Gross Domestic Product (GDP) and the demand for freight transport" (1). Nevertheless, we may note, as an aside, that it is in this long-term context that the independent treatment of the demand and supply aspects is less justifiable.

There may be, as some have argued, no reason to doubt the long-term relationship between GDP and freight transport demand. But discovering this relationship exactly is perhaps more difficult than is commonly supposed. An early study of this subject in the last decade by Hall (3) concluded that the volume of freight could be expected to grow more slowly than GDP and that this disparity would be less the faster the economy grew. The results of Hall's analysis were approximately consistent with the forecasts contained in a Ministry of Transport report (4) published nearly 5 years later. However, they were very much at variance with the findings of a 1964 study (5) (Table 2). Chisholm (6) has recently extended this type of analysis principally by taking a longer time series. His analysis showed that a 2.7 percent increase in GDP from 1953 to 1968 gave rise to an annual increase in all freight of 2.2 percent and a ratio of 0.82, one higher than the corresponding ratio used for forecasting in Hall's study.

One reason perhaps for some of these apparent contradictions is that a change has been taking place in the long-term relationship between economic growth and freight transport. Beckerman and Associates noted that prior to 1957 the tendency was for freight movements to expand at a slower rate than the economy. Tulpule (7), analyzing later statistics, suggested that between 1958 and 1963 the amount of freight traffic and GDP increased by similar proportions, whereas after 1963 ton-miles grew at a faster rate than GDP. This evidence strongly suggests that the underlying trend in the United Kingdom is toward a more transport-intensive economy.

It is difficult therefore to share the confidence of some (6) that a simple linear correlation between GDP and freight ton-miles provides an adequate indication of the future demand for freight transport services. Until we disentangle the underlying trend it is difficult to share Sharp's optimism that a stable long-term relationship exists.

It is perhaps an interesting comment that the period during which the British economy appeared to change from a position of inelasticity to one of elasticity, in terms of the associated transport coefficient, was a time of rapid growth of investment in highways and a time when structural developments in the truck industry meant that freight rates were falling in real terms (8). Once again it places stress on the interrelated nature of the demand and supply forecasts involved, when growth in the number of freight vehicles is predicted.

TRENDS IN THE SUPPLY FACTORS

Let us now turn to the supply side of the equation. Of interest here is the influence of public policy and, in particular, the effect it has had on the use and carrying capacity of the average vehicle.

A feature of the last decade has been a rapid change in policy with regard to regulations governing the construction and use of trucks. Table 3 gives a chronological selection of these changes.

In addition, there have been changes in taxation policy bearing either directly or indirectly on the truck industry. And, more in the background, but not without significance, there has been continual technological progress such as the improved design of tractor-trailer combinations.

The apparent effect on the truck industry of these developments has been dramatic (Table 4). In spite of large increases in average vehicle carrying capacity, load factors have fallen only slightly. This together with an increase, albeit small, in the annual miles run per vehicle has produced a very large increase in vehicle productivity.

The extent to which such increases in productivity are to continue would appear to be very much a matter for transport policy. If, as it seems reasonable to assume, larger trucks have been instrumental in boosting the trucking industry's productivity because of changes in the construction and use regulations, future increases in this productivity are by no means ensured. The recent public reaction to the detrimental environmental effects of larger trucks has been too pronounced for this to be assumed with certainty. And yet the correct prediction of changes in productivity could be a vital factor in determining the total size of the truck industry. Calculations by Sharp illustrate this and are given in Table 5. These calculations show, for instance, a difference of a million trucks by the year 2000 if, instead of stagnating, carrying capacity (and its utilization) grows at 2½ percent per annum.

We can thus appreciate that the future national stock of trucks is the outcome of the interplay between a large number of factors. The situation is exceedingly complex and

Table 1. Indexes of the number of registered general freight vehicles in Great Britain (excluding Northern Ireland).

Date	Unloaded Weight <1½ Tons	1½ to 3 Tons	>3 Tons	Total[a]
1960	100	100	100	100
1961	104.9	94.8	114.3	103.9
1962	107.1	89.1	122.7	105.3
1963	111.6	87.4	135.3	109.5
1964	115.3	83.6	147.1	112.6
1965	114.3	77.3	155.0	111.9
1966	111.8	70.7	161.8	110.0
1967	115.6	69.3	171.0	112.9
1968	110.6	64.7	173.1	109.8
1969	116.4	58.0	172.7	111.3
1970	123.2	56.6	176.9	115.6 (111.1)
1971	124.3	54.3	178.6	115.9 (111.3)
1972	129.4	54.6	172.3	117.7 (113.3)

[a]After 1969 the Post Office Corporation's vehicles were no longer exempt from licensing. The index in parentheses continues the series minus the number of Post Office vehicles that entered the statistics in 1970.

Table 2. Growth in freight traffic related to growth in U.K. economy.

Study	Date	Analysis Period	Forecast Period	Type of Freight	Ratio of Growth of Inland Freight to Growth in GDP: Actual	3 Percent GDP Growth[a]	3.5 Percent GDP Growth[a]	4 Percent GDP Growth[a]
Hall	1963	1952-60		General	0.9			
			1960-80	General		0.9		1.2
			1960-80	All		0.65		0.85
Beckerman	1964	1952-62		General	1.48[b]			
				All	0.94[b]			
			1960-75	General			1.23	
			1960-75	All			0.94	
Chisholm	1971	1953-68		All	0.82			
MOT	1963		1966-75	General		1.00		
	1967		1966-75	All		0.60		

Note: There are slight differences in the base statistics or assumptions used; e.g., Beckerman's all freight estimate excluded freight by passenger railroad, but these are not considered to account for the substantial differences between the statistics shown.

[a]Assumed.

[b]Based on rate of increase in GDP experienced during 1950-60.

Table 3. Changes in regulations relating to construction and use of trucks in the United Kingdom.

Date	Regulation Change
1962	Speed limit raised from 30 to 40 mph for trucks over 3 tons (unloaded weight)
1964	Permitted maximum weight and size of tractor trailer combinations raised from 24 to 20 tons gross and 35 ft to 42 ft 8 in.
1968	Permitted maximum size of tractor trailer combinations raised from 48 ft 8 in. to 49 ft 2 in.
1968	Trucks less than 1½ tons (unloaded weight) released from all licensing restrictions on carriage
1970	Abolition of the need for a second driver for truck and trailer combinations
1970	By December all trucks freed from carriers licensing
1971	Speed limit raised from 40 to 50 mph for trucks under 1½ tons (unloaded weight)
1972	Permitted maximum weight of "rigid" trucks raised from 28 to 30 tons

Table 4. Capacity utilization of heavy trucks.

Date	Average Carrying Capacity (tons)	Miles per Truck	Average Ton-Miles per Truck	Tons Carried per Truck-Mile	Tons Forwarded per Capacity Ton-Mile	Ton-Miles per Capacity Ton
1960	4.67	16,400	43,000	2.99	0.65	10,600
1965	5.71	17,400	63,400	3.64	0.64	11,100
1969	6.79	18,600	77,900	4.19	0.62	11,500

very difficult to forecast with confidence. Nevertheless, even though precise statistical analysis of relevant variables might be absent, common sense tells us that we should take account of these factors if only by guessing their effect on the overall situation. Whether U.K. transportation studies have done so is a subject to which we now turn.

CONTROL TOTALS IN TRANSPORTATION STUDIES

The situation for some of the recent and larger studies is given in Table 6. It merely gives a broad indication, inasmuch as the methods used varied widely and they did not conform to a standard pattern. The important columns are 4 and 9. Consideration of the latter, for example, implies some consideration of columns 6, 7, and 8, although it is preferable that the assumptions regarding these component parts be made explicitly. The symbol ∅ signifies that this has been done in the case of any particular study. It will be seen that in the majority of instances such explicit consideration of factors has been disregarded.

The Greater Manchester and London studies, in essence, developed trend forecasts in vehicle registrations. The West Yorkshire and Merseyside studies on the other hand gave careful consideration to the growth in GDP, to modal competition, and to increases in average vehicle loads but ignored one important dimension of output, mileage, in deriving their control totals. These latter totals were expressed as trips per capita. The Belfast study used industrial production as the key demand variable and took account of "increased efficiency in utilization" of truck capacity in arriving at the growth in registrations.

With regard to the division of the vehicle stock between different size categories, the West Midland, Belfast, and Manchester studies decided on this division after the basic forecast. The West Midland study, for example, assumed a constant proportion of light pickup trucks, whereas the Belfast study took into account recent trends in the composition of the vehicle stock.

We must conclude that for the most part the study forecasts were of a rudimentary nature and ignored many of the important factors involved in the overall situation.

In spite of the vital importance of the control totals in the general freight model, there has been no attempt to consider whether the final outputs from this model have been consistent with the assumptions, implicitly or explicitly, included in the separate forecast of the control. For the most part this is understandable; the output characteristics are generally not in a form that would permit such checking. There is, however, one possible exception. This depends on the forecast of the control being based on an explicit assumption regarding the average length of haul or total truck mileages and on the distribution model providing an average trip length output. (In developing the "control" it is normal to assume that in the future the number of trips per truck will remain the same as at the present time. Because of this, total truck mileages can readily be converted to average trip lengths.) In these circumstances it is possible to check whether the average increase in trip length from the distribution model is consistent with that assumed in forecasting the control totals. Thus, we might envisage a model restructured as shown in Figure 1 with the overall model being recycled until a satisfactory consistency is achieved.

ZONAL FORECASTS

We have already touched on some of the features and weaknesses of the typical trip end model used to develop the zonal forecasts. The typical trip end model includes, as independent variables, factors such as employment, resident population, and retail sales, perhaps stratified for different industrial or commercial groups. It has already been pointed out that these factors are essentially land use variables and that they are of limited use for examining different traffic and transport policies that have implications for the movement of freight.

Nevertheless, even in the more restricted context of explaining the effect of land use change on freight movements, the model often has serious weaknesses. The general procedure adopted has been based on the use of zonal aggregates with each traffic zone treated as one observation. Oi and Shuldiner (9) and Douglas and Lewis (10), among

Table 5. Estimates of total future numbers (in millions) of heavy trucks.

	Annual Growth in Carrying Capacity			
Date	1 Percent	None	+2.5 Percent	+5 Percent
1970		0.63	0.63	0.63
1975	0.78	0.73	0.64	0.56
1980	0.99	0.88	0.67	0.51
1985	1.25	1.05	0.70	0.47
1990	1.56	1.26	0.73	0.44
1995	1.99	1.49	0.76	0.40
2000	2.49	1.76	0.78	0.37

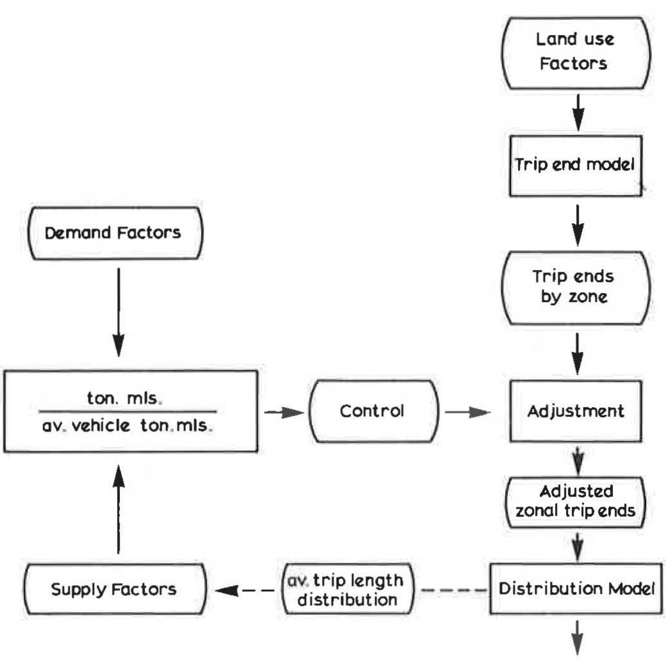
Note: The following assumptions are made: A linear relationship exists between GDP and total inland freight and GDP grows 3 percent per annum, and ton-miles by rail are constant.

Table 6. Control totals developed in selected U.K. transportation studies.

Study (1)	Truck Type[a] (2)	Influence of GDP on: Tons (3)	Influence of GDP on: Ton-Miles (4)	Rail Competition (5)	Δ Avg Carrying Capacity per Vehicle (6)	Δ Loads or Load Factors (7)	Δ Miles per Vehicle or Avg Length of Haul (8)	Δ Ton-Miles per Vehicle (9)
W. Yorks (1957-68)[b]	HCV	φ		φ constant percentage		φ		
	LCV	φ		φ constant percentage		φ		
Merseyside (1966-69)	HCV	φ		φ constant percentage		φ		
	LCV	φ		φ constant percentage		φ		
W. Midlands (1964-68)	LCV } HCV }		φ		φ	Constant	φ	φ
London (1962-68)	LCV } MCV }			Trend forecast in registration				
	HC		φ	Adjusted trend forecast in registrations				Constant
Belfast (1965-69)	LC } MCV } HCV }	φ		N.R.[c]	φ	φ	φ	
Greater Manchester (1965-71)	LCV } HCV }			φ constant quantity	Trend forecast			

[a]HCV = heavy commercial vehicle, ≥1½ tons; MCV = medium commercial vehicle, ≥3 tons; LCV = light commercial vehicle, <1½ tons, all unloaded weight.
[b]Approximate starting and completion dates.
[c]Rail competition not relevant.

Figure 1. An iterative truck forecasting model.



others, have pointed out the serious weaknesses of a grouped data approach in a forecasting context, and, as a consequence, person trip end analysis is now based on the household. This suggests that forecasts of truck activity at the zonal level should also be based on the unit of behavior, i.e., the firm or business organization. But prerequisite to such an approach is an ability to predict the necessary land use inputs, such as the number, type, and size of business units. Of course, at the present such an approach is not really possible.

Understandable though the use of grouped data might be at the present time, this does not absolve the transport planner from blame for poor statistical analysis, which is a characteristic of many studies. The main statistical failings involve the assumptions associated with the use of linear regression, the preferred statistical method in most studies. The chief assumptions are as follows.

1. The relationships should be linear. There is some evidence that this is not always so (11, 12).
2. Independent variables should be linearly independent of each other. The frequent practice of indiscriminantly putting all conceivable factors into a multiple regression suggests that this is unlikely to be the case. The outcome will be coefficients that, over a period of time, are unstable and therefore of little value for forecasting.
3. The variance should be homoscedastic or constant; i.e., the variation around the line of best fit must be independent of the observed values of each variable.

Recent models of person movement have avoided these stringent assumptions by using cross-classification analysis (referred to as category analysis in the United Kingdom). This is a superior method of averaging sample data over predetermined categories (or steps) in the relevant variables. But, unfortunately, as traditionally applied in the United Kingdom, the analysis produces no error terms in relation to the estimated coefficients (i.e., trip rates per category).

Therefore the use of cross-classification methods does depend on a confident specification of the causal variables and on a level of analysis that avoids the use of grouped data. Such methods are not recommended for application in their present form to freight movements where, generally speaking, these conditions are not fulfilled.

An alternative approach to these statistical problems is to use logarithmic (and other) transformations or dummy variables within the framework of regression analysis. For example, if properly applied, dummy variable analysis can give results similar to (or in the extreme case identical with) cross-classification methods and, in addition, provide the analyst with far more information on the accuracy of his model. The dummy variable method has been applied in freight movement studies by Starkie (13).

CONCLUSION

Recent experience of forecasting urban truck trips in the United Kingdom has highlighted weaknesses of present methodologies in relation to a proper examination of policy variables. Nevertheless, progress is more likely to stem from an improvement in the fundamentals of the present approach. Ad hoc studies can and will provide useful information on the effect of different policies, but their methods will complement rather than supersede those currently in use.

Within the context of present methods, more care and attention should be given to forecasting the control totals in view of their key role in the overall prediction. Further improvement might follow from a disaggregation of the control totals for specified economic sectors and for different regions and subregions.

With regard to the forecast of truck trips on a zonal basis, U.K. studies will benefit greatly if more attention is given to the quality of their statistical analysis. In this context too, special studies, in this case of freight movements to and from industrial plants, can usefully guide and supplement the basic approach. At the present time they are unlikely to provide the basis for a new forecasting methodology.

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THE ROLE OF TERMINAL CONSOLIDATION IN URBAN GOODS DISTRIBUTION

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The purpose of this study was to examine the impact of routing urban small freight transport through a consolidated terminal. The characteristics of vehicles making pickup and delivery shipments ranging from 1 to 5,000 lb in the Columbus, Ohio, CBD on a typical business day by both private and for-hire carriers were examined, as was the effect of a consolidated terminal on these characteristics. The vehicle characteristics studied include the number and types of vehicles; vehicle capacity utilization; distance traveled and air pollutants emitted within the CBD; aggregated daily transit, unloading, and loading times and queuing time prior to loading or unloading; and pickup and delivery costs measured by applying a standard hourly cost to the total vehicle time within the CBD. A simulation technique was used, and data were collected through a cordon survey and driver interviews. The findings of the study indicate that the simulation model validly replicated freight flows. When these shipments were routed through a consolidated terminal, a 90 percent reduction in vehicle flow resulted, with a 73 percent reduction in vehicle operating costs, which represents an annual savings of approximately $2 million.

•IN RECENT YEARS, the problem of transporting small shipments of general freight by motor carrier within an urban center has surfaced as "the most important U.S. transportation problem of the 1960s" (1). The chairman of the Transport Technology Committee of the Transportation Association of America (2) recently concluded, "Our metropolitan areas are being strangled by the inefficient movement of goods—the lifeblood of any city."

Perhaps the most significant cause of the high costs of urban goods movement and the resulting congestion and pollution caused by a multitude of trucks serving a given area is the uncoordinated method of picking up and delivering small shipments. From the carrier's viewpoint, information indicates that this is high-cost service. For example, the national operating ratio (3) for shipments of less than 500 lb is 132.5. In addition, the operating costs in New York City have been estimated to be 112 percent greater than in surrounding areas (4).

The problem is not only economic but also social. Insofar as more commercial vehicles are involved than are necessary, they interfere with the efficient movement of people, contribute to the high air pollution levels in major urban centers, and represent a significant drain on the nation's already scarce supply of energy.

Various solutions have been proposed to the urban congestion-small shipment problem. Among these are temporal or spatial separation of freight and passenger movement, revision of building codes and zoning ordinances, improvements in traffic engineering and street design, and consolidation of pickup and delivery service through a centralized terminal. After studying the impact of each of these proposed solutions, Battelle Research Institute (5) recommended a terminal consolidation approach as having "the highest priority in solving urban congestion," and the National Research Council concluded that in-depth study is urgently needed.

Previous studies on the feasibility of consolidating urban small shipment pickup and delivery service have shown the expected benefits to be substantial. A study done in

New York City by the Tri-State Regional Planning Commission found that commodities brought into the city by 28 carriers were redistributed by 4,200 smaller delivery trucks. The estimated annual savings (6) of a consolidated system under these conditions was $95 million, representing an 8 percent annual savings. In a similar study of downtown Philadelphia, it was estimated that the center city area could effectively be served by from 40 to 60 trucks (7). An investigation of a large Canadian urban center revealed that a 9 percent cost savings could result from a consolidated approach (8), and a simulation study found that the cost savings of consolidating small goods movement in a city of 500,000 were significant (9). In June 1972 the Urban Mass Transportation Administration allocated funds to the Ohio State University (OSU) to examine the economic and social impact that a consolidation terminal might have in a typical metropolitan area such as Columbus, Ohio.

UMTA-OHIO STATE UNIVERSITY STUDY

The scope of the UMTA-OSU study includes an examination of the movement of goods ranging from 1 to 5,000 lb into and out of the Columbus CBD by private and for-hire carriers stationed outside the CBD. The Columbus CBD has an area of approximately 900 acres and contains approximately 20 million square feet of floor space. The breakdown of this total floor space by land use category is 62 percent office space, 16 percent retail goods space, 13 percent industrial space, and 9 percent retail services space.

Vehicle characteristics associated with these shipments included the following:

1. The number and types of vehicles;
2. Vehicle capacity utilization;
3. Distance traveled and air pollutants emitted within the CBD;
4. The aggregated daily transit time, unloading time, loading time, and queuing time prior to loading or unloading within the CBD; and
5. Pickup and delivery costs, as measured by applying a standard hourly cost to the total vehicle time within the CBD.

Excluded from the study scope were organizations that specialize in small shipment distribution, namely the Postal Service, United Parcel Service, and Railway Express Agency.

The 2-year study involved measuring the impact of routing the measured daily demand through a consolidated terminal on the above vehicle characteristics. The experimental technique of simulation was used.

Data Collection Procedure

Data were collected by conducting a cordon survey in which general freight trucks were counted and classified as they entered the Columbus CBD, and the drivers were interviewed and given a trip data form to complete as they made their stops within the CBD. Each general freight truck entering the CBD was classified by ownership, i.e., private or for-hire, and by size, i.e., small, intermediate, or large. Drivers were asked the purpose of their trips, the number of stops to be made within the CBD, the rate of the vehicle capacity utilization, and the total weight and number of pieces to be delivered within the CBD. Highly detailed data were provided by the drivers who completed the trip data form. These data consisted of the location and purpose of each stop; the time of arrival and departure; the number of pieces, total weight, and commodity description of goods delivered and picked up; and the waiting or queuing time at each stop prior to loading or unloading.

A total of 13 data collection stations, each staffed by three to five individuals, were set up over a 2-day period, November 14 and 15, 1972. Some 50 percent of the approximately 900 general freight trucks entering the CBD stopped for the interview, and 20 percent of the drivers receiving a trip data form completed and returned it. This represented a 10 percent sample of the total general freight vehicle flow.

Survey Results

The survey results indicate that approximately 1,850 commercial vehicles enter the

Columbus CBD between 8 a.m. and 5 p.m. on a typical business day, and about 900 or 48 percent of these are general freight trucks. (The remaining 950 vehicles, which were excluded from the scope of the study, consisted of service or repair vehicles, government and construction vehicles, and trucks transporting perishable products, such as meat, frozen foods, produce, bread, and beverages.) Vehicles delivering or picking up single shipments greater than 5,000 lb, those merely passing through the CBD, and those returning to their home base within the CBD were deducted from this total. These adjustments resulted in 660 vehicles delivering or picking up general freight shipments that have the potential to be consolidated.

Vehicle Characteristics—Of the 660 vehicles considered, 50 percent were straight delivery trucks, 26 percent were pickup or panel trucks, and 24 percent were semitrailer combinations. Slightly more than 62 percent of the total were private vehicles, and 38 percent were for-hire vehicles.

At the interview point, those drivers making deliveries were asked to estimate the cubic capacity utilization of their vehicle. Of the for-hire vehicles, 74 percent were estimated to be less than 50 percent utilized, with a mean of 38 percent and a median of 34 percent. Of the private vehicles, 88 percent were estimated to be less than 50 percent utilized, with mean and median measures of 28 and 24 percent.

The total distance traveled within the CBD by the 660 vehicles was determined by tracing and measuring the actual routes traveled by those vehicles whose drivers returned the detailed trip data form. This was accomplished by plotting the movements on a map of the CBD with a scale of 1 in. = 200 ft. These results were then aggregated and assumed to be representative of all vehicles. The average speed of these vehicles was determined to be 5.2 mph—a result obtained by dividing the total distance traveled, 1,276 miles, by the total transit time, 244 hours.

Unloading deliveries required 392 hours, and 81 hours were required to load pickups. These values were computed as functions of the weight delivered or picked up at each stop. Finally, the queuing time, a measure of the degree of congestion at shipping and receiving docks within the CBD, totaled 251 hours.

In summary, the total daily vehicle time within the CBD was 968 hours, with a distribution of 25.2 percent for transit, 40.5 percent for unloading, 8.4 percent for loading, and 25.9 percent for queuing.

Costs and Pollutants—The daily cost of providing pickup and delivery service was computed by applying a standard hourly cost to the total time that each type of vehicle spent in the CBD. This was calculated to be $11,750.

The air pollutant emissions of the general freight commercial vehicles were as follows:

Pollutant	Amount (lb)
Carbon monoxide	460
Hydrocarbons	108
Oxides of nitrogen	36

These measures were computed by applying standard 1973 emission levels per mile for each vehicle type, assuming an average speed of 5.2 mph.

Demand Characteristics—The 660 vehicles carrying consolidatable freight delivered 2,460 shipments, totaling 1,132,000 lb, and picked up 570 shipments, totaling 237,000 lb. Whereas for-hire vehicles only accounted for 38 percent of the vehicle flow, they made 63 percent of the total deliveries and 69 percent of the total pickups.

When this demand was analyzed by land use category, 20 percent of the deliveries and 29 percent of the total weight were destined for retail goods outlets; 26 percent of the shipments and 15 percent of the weight were destined for retail service outlets; 25 percent of the shipments and 44 percent of the weight were destined for industrial operations; and 20 percent of the shipments and 20 percent of the weight were destined for office buildings. Combining all the delivery shipments by weight class revealed that 39 percent of the shipments were less than 100 lb, 20 percent were from 101 to 200 lb, 18 percent were from 501 to 1,000 lb, and 10 percent were from 1,001 to 5,000 lb.

Analysis by land use category of the pickups made within the CBD indicated that 68 percent were made at industrial sites, 21 percent at retail goods outlets, and 11 percent at office buildings.

OVERVIEW OF THE SIMULATION MODEL

A simulation model was developed to analyze the effects of small shipment consolidation. The assumptions of the model are as follows:

1. The consolidated terminal location is on the northern fringe of the CBD;
2. The CBD is divided into 10 zones, and vehicles dispatched from the terminal make deliveries and pickups in only one of the 10;
3. The distance a vehicle travels each time it is dispatched from the terminal to a particular zone is deterministic and was computed by tracing the most efficient route a vehicle would take to travel to its zone from the terminal, "sweep" the alley network of its zone, and return to the terminal;
4. The weight capacity of a delivery vehicle is 17,000 lb, which corresponds to the average capacity of a 28-ft semitrailer combination;
5. The average speed of a 28-ft semitrailer is 5.2 mph;
6. Deliveries arriving at the terminal prior to a predetermined cutoff time will be delivered that same day (in all cases deliveries will be made within 24 hours);
7. Because deliveries and pickups of small shipments operate to and from a particular zone, queuing time at docks within the CBD prior to loading or unloading is assumed to be eliminated; and
8. The number of delivery and pickup stops made by each 28-ft semitrailer is selected stochastically from ranges of 8 to 12 and 3 to 5 respectively.

The exogenous variables, or inputs to the model, are the arrival or generation patterns of the delivery and pickup shipments. These measures are generated stochastically based on the demand of the system measured by the cordon survey.

The endogenous variables, or outputs of the system, are the number of trucks dispatched from the terminal; total mileage traveled; total transit, unloading, and loading times; and number of trucks required in the terminal fleet. Costs are computed by applying a standard hourly rate to the sum of the transit, unloading, and loading times. The air pollution emissions of the terminal fleet are calculated by applying 1973 standard emission levels per mile for the defined vehicle type and an average speed of 5.2 mph.

The simulation language used in the model is GPSS/360, which generates transactions as the units of traffic being routed on a defined sequence or course through the stages of a model. Transactions signify delivery or pickup shipments. As each transaction is generated, it is assigned parameter values representing its land use destination or origin. These parameter assignments are made stochastically based on probability distributions resulting from the survey. The shipment weight and zone destination or origin are functions of the land use parameter value.

Deliveries are then accumulated on the terminal dock in a location that corresponds to the zone destination. When either 17,000 lb is accumulated or the cutoff time for the last delivery of the day arrives, the delivery truck is loaded and dispatched to one of the 10 zones to make the deliveries as well as the pickups from that zone, which have also been accumulating. The unloading and loading time of each vehicle is a function of the number of stops and the total weight delivered or picked up. The transit time of each vehicle is a function of the distance traveled.

Model Experimentation

Experiments were conducted on the model to test its sensitivity to changes in truck size, zone configuration, size of shipments, prepaid shipments, and level of demand. More specifically, the following changes were examined.

Vehicle Size—Initially the vehicle size used in the model corresponded to a 28-ft semitrailer combination. This has been changed to determine the effect of using a delivery truck with a capacity of 10,000 lb, as well as a 40-ft semitrailer combination with a capacity of 24,000 lb.

Zone Configuration Within the CBD—The initial breakdown of 10 zones has been revised to a configuration of four zones.

Consolidated Terminal Domain—Initially the terminal domain was all shipments less than 5,000 lb. This was revised to include only private shipments less than 5,000 lb, only for-hire shipments less than 5,000 lb, and all shipments less than 1,000 lb.

Effect of Prepaid Shipments—Because no measure was obtained on the proportion of prepaid delivery shipments made within the CBD in the cordon survey, it was assumed that 50 percent of the delivery stops involved prepaid shipments. The model tested the impact of 5- and 10-minute savings at each stop resulting from prepaid shipments.

Sensitivity Analysis—The demand level was modified to test the impact of several system load levels.

Preliminary Results

Tables 1 and 2 give summary survey data related to shipments by type of carrier and shipment weight class. These data were among the basic inputs to the simulation model experiments.

Table 3 gives the results of the simulation model experiments when the zone configuration within the CBD, vehicle size, and terminal domain were varied. (Several model experiments were conducted in addition to those reported on in Table 3, but space does not permit further exposition of those results at this time.)

One special caution is in order at this point. The benefits soon to be ascribed to consolidating small shipments are intuitively obvious. However, just as obvious are the costs associated with building, operating, and maintaining a terminal facility that permits these economies to be achieved. These costs are currently being calculated and, therefore, cannot be included in the calculations that follow. Consequently, the benefits of delivering consolidated small shipments do not include the actual costs of bringing together these shipments for consolidated delivery. As given in Table 3, the greatest benefits resulted from routing all shipments of less than 5,000 lb through the consolidated terminal with a 10-zone configuration via a 28-ft semitrailer. The expected benefits were a vehicle flow reduction of 90 percent and an annual savings of approximately $2,102,500. These benefits required an average fleet of 38 vehicles, representing an investment of about $475,000.

When demand measures are further revised to include only those shipments less than 1,000 lb (2,205 deliveries weighing 525,000 lb and 520 pickups weighing 107,000 lb), there are a vehicle flow reduction of 76 percent and an annual savings of some $1,760,000. These benefits require an average fleet of 20 vehicles, representing an investment of approximately $250,000. The expected savings of a terminal domain including all shipments less than 1,000 lb equal 84 percent of the expected savings of the much larger terminal domain including all shipments less than 5,000 lb. A comparison of the benefits of the two terminal domains is given in Table 4.

The air pollution emissions associated with those vehicles within the scope of the study were also calculated. These totals were equal to approximately 5 percent of the total daily air pollution emissions from mobile sources within the CBD. As a result, even though approximately 80 to 90 percent of the vehicle mileage would be eliminated through a consolidated terminal operation, the reduction in total daily mobile source pollutant levels would not be significant.

SUMMARY

The preliminary results of this ongoing investigation indicate that substantial economic benefits might be realized by implementing an urban consolidated terminal. These benefits can best be described in relation to the various actors in the system, namely, those who are internal to the service, i.e., the carriers and shippers, and those who are external to the service, i.e., consumers, society, and government.

Although no comparisons of revenues and operating costs of the carriers were made in the study, the data would seem to support previous studies pointing out how unprofitable small shipment distribution is within an urban area. Factors supporting this belief include the low average vehicle capacity utilization, low average vehicle speed,

Table 1. Relative demand levels.

Demand Measure	Total System	Type of Carrier: Private No.	Percent	For-Hire No.	Percent	Shipment Weight: <1,000 Lb No.	Percent	1,000 to 5,000 Lb No.	Percent
Deliveries									
Number	2,460	905	37	1,555	63	2,205	90	255	10
Weight, lb	1,132,000	256,000	23	876,000	77	525,000	46	607,000	54
Pickups									
Number	570	175	31	390	69	520	91	50	9
Weight, lb	237,000	47,000	20	190,000	80	107,000	45	130,000	55

Table 2. Allocation of current system performance measures.

Performance Measure	Total System	Type of Carrier: Private No.	Percent	For-Hire No.	Percent	Shipment Weight: <1,000 Lb No.	Percent	1,000 to 5,000 Lb No.	Percent
Number of trucks	660	410	62	250	38	535	81	125	19
Distance traveled, miles	1,276	638	50	638	50	1,085	85	191	15
Time, hours									
Transit	244	122	50	122	50	207	85	37	15
Unloading	392	89	23	303	77	267	68	125	32
Loading	81	19	23	62	77	55	68	26	32
Queuing	251	57	23	194	77	170	68	81	32
Cost, dollars	11,750	2,950	25	8,810	75	8,660	74	3,090	26

Table 3. Summary of experimental results.

Performance Measure	Current System	Consolidated Terminal: All Shipments <5,000 Lb: 4 Zones, 28-Ft Trailer	10 Zones: Straight Truck	28-Ft Trailer	40-Ft Trailer	10 Zones, 28-Ft Trailer: Private, <5,000 Lb[a]	For-Hire, <5,000 Lb[b]	All Shipments <1,000 Lb[c]
Number of trucks	660	66	111	69	52	271	466	161
Distance traveled, miles	1,276	176	182	114	85	683	728	250
Time, hours								
Transit	244	34	28	22	22	129	139	48
Unloading	392	207	210	186	192	346	232	224
Loading	81	61	53	51	53	73	60	58
Queuing	251	–	–	–	–	100	57	34
Daily costs, dollars	11,750	3,902	3,384	3,340	3,794	8,387	6,211	4,711
Annual savings, dollars		1,962,000	2,091,500	2,102,500	1,989,000	841,000	1,550,000	1,760,000
Trucks in fleet[d]		39	57	38	34	13	32	20

[a]The performance measures include the daily averages of the model outputs for the simulated week plus the performance measures of the for-hire vehicles given in Table 2. The 271 trucks in the system include the 250 for-hire vehicles, the current system measure, plus the 21 vehicles dispatched from the terminal.
[b]The performance measures include the daily averages of the model outputs plus the performance measures of the private vehicles given in Table 2.
[c]The performance measures include the daily averages of the model outputs plus the performance measures of shipments from 1,000 to 5,000 lb given in Table 2.
[d]Power units.

Table 4. Comparison of demand, benefits, and fleet costs of proposed terminal domains.

Measure	Shipments <5,000 Lb	Shipments <1,000 Lb
Total demand		
Number of deliveries	2,460	2,205
Delivery weight, lb	1,132,000	525,000
Number of pickups	570	520
Pickup weight, lb	237,000	107,000
Expected benefits		
Total number of vehicles to service CBD	69	161
Vehicle flow reduction, percent	90	76
Annual savings, dollars	2,102,500	1,760,000
Fleet requirements		
Number of vehicles	38	20
Fleet investment, dollars	475,000	250,000

duplications of routing, and substantial time spent queuing at docks prior to loading or unloading. With a consolidated terminal handling the pickups and deliveries of small shipments within the CBD, carriers would be able to allocate their resources to more profitable operations.

Because of the high volume attained by the terminal, the application of existing technology such as computerized routing and sorting, containerization, and automated materials handling methods would become more economically feasible and might result in further improvements in the efficiency of these operations.

From the viewpoint of the shippers or receivers, the operation of a consolidated terminal would minimize dock time necessary for loading and unloading, leaving their employees free for other uses. Instead of deliveries from numerous vehicles throughout the day, each receiving point would be visited by one or a few vehicles dispatched from the terminal. A more reliable service level might also be expected at lower cost, because of the economies of scale inherent in consolidated terminal operation.

As previously mentioned, the net expected economic benefits of the total terminal operations cannot be determined until terminal construction and operation costs are compared to the savings of the pickup and delivery fleet. However, societal benefits certainly would include a significant reduction in commercial vehicle traffic within the CBD and significant savings in fuel consumption. From the viewpoint of governmental officials, the transportation planning process of efficiently moving people and freight into and out of the CBD would be simplified.

This study has attempted to conceptualize a method of improving the efficiency of urban goods distribution while minimizing the societal by-products inherent in this process. In light of the current environmental trends of consumerism, concern about energy reserves, and the increasing emphasis on improving the quality of life of urban residents, a revised approach seems necessary. All indications are that the problem of urban small shipment distribution as measured by increasing costs, deteriorating service, congestion, pollution, and the decline in economic viability of urban regions will get worse. The continued trend of urbanization, increased dependence on motor carriers for freight distribution, and the predicted increase in the number of small shipments all add momentum to the increased congestion and costs of urban commercial vehicle traffic.

Current research in business must evaluate decisions in terms of both economic and social criteria. The distribution of consumer and industrial goods is not an end in itself, but must act in concert with the broad public interest. The results of this study may assist in spurring definitive action on the part of city planners, other government officials, carriers, and shippers to insist on thorough examination of urban consolidated terminal operations as a viable solution to the upward spiral of costs associated with urban small shipments.

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TOWARD A UNIFIED DISTRIBUTION SYSTEM-WAREHOUSE LOCATION THEORY

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Many of the problems of urban goods movements may be related to the present methods of analyzing freight distribution systems in urban areas. This paper considers the problems associated with the physical distribution of freight, as well as the problems of distribution center location. The authors suggest that these two areas are very much interrelated and should be considered together as components of a single system. An extensive literature review of freight distribution and terminal location research is presented with special reference to the feasibility of designing a unified distribution system-terminal location theory. Also an attempt is made to match theoretical approaches and insights with the practical requirements and concerns of freight distribution in urban areas. The authors conclude that much of the purely theoretical work has little, if any, relevance to the solution of real-world distribution and location problems. It can be concluded that serious faults underlie component-by-component analysis of the distribution system. This approach is questionable because the performance of the whole system is the decisive element in the functioning of a distribution system, rather than the individual operation of its components.

•A SUBSTANTIAL PORTION of the ongoing research on urban goods movement is concerned with identifying the interrelationships of freight transportation and the urban area. These relationships address problems such as the joint use of transportation facilities for freight and passenger service; space requirements for shipping and receiving operations; and legal, regulatory, labor, and financial constraints associated with the distribution of freight in urban areas.

Many of the problems encountered with urban goods movement can be identified by investigating the theoretical and practical methods of analyzing freight distribution systems in urban areas. The inadequacies of these techniques, both methodological and structural, may provide insights into the appropriateness of these models and techniques in analyzing processes of urban goods movements. Many of the suboptimalities experienced in urban goods movements may be related to the incomplete and perhaps erroneous analysis of a firm's distribution system. We may define the physical elements of a distribution system as one or more terminals (warehouses, depots), a set of routes between these terminals and the consignees serviced by the system, and vehicles that routinely transport the freight within this system.

Terminals are included in the distribution system because their functions are directly related to the objectives of the actual physical distribution of freight. Terminals break down line-haul shipments into smaller lots for distribution to individual consignees, act as intermediate storage points (between the primary producers and the consignees) to provide "production smoothing" of the flow of goods to the consignees, and provide for the transferral and reassembly of freight (break-bulk operations) from the incoming method of transportation to that of the outgoing method. This latter point does not necessarily indicate that there must be a change of mode.

This paper is concerned both with the problems associated with a physical distribution system as a whole and with the problem of distribution center location. The two problem areas are so intertwined that they must be considered simultaneously as interrelated components of a single system. The logical basis for developing, operating, and financing a unified freight distribution system in an urban area must be the consideration of warehouse location, which takes into account the other elements of the total distribution system.

For ease and clarity of exposition, the authors have chosen to discuss the literature on terminal location and distribution system problems separately. As will be shown later, research in the two areas tends to make different assumptions about the given and the unknown elements of the overall system.

The three major objectives of this paper are to analyze the state of the art of freight distribution and terminal location research and to investigate the feasibility of designing a unified distribution system-terminal location theory based on a critical analysis of the literature. A third objective is to attempt to match theoretical approaches and insights with the practical requirements and concerns of freight distribution in urban areas. We concluded very early in the research effort that much of the purely theoretical work had little, if any, relevance to the solution of real-world distribution and location problems.

WHY A UNIFIED THEORY OF WAREHOUSE LOCATION AND DISTRIBUTION SYSTEM ANALYSIS?

A large number of contributions to the literature on warehouse location and physical distribution analysis have been made by operations researchers, management scientists, and management consultants. These groups tend to have highly specialized interest in specific components of the distribution system. This orientation has resulted in many models and heuristic methods for accomplishing warehouse location, design, and operation; fleet scheduling, routing, and size; inventory analysis and control; and service area definition for a warehouse. A particular characteristic of the mathematical models is that they depend on information inputs from other components of the distribution system. Many of these data requirements, however, cannot be met for a practical application of the model. Also, mathematical modelers are often forced to make simplifying assumptions about the behavior of other components of the distribution system to facilitate the application of their models. The result is a patchwork of optimization methods that do not realistically describe the components of the distribution system. These methods, in almost all of the studies examined, did not produce useful information on operation of the particular component being investigated, which could be used as input for the analysis of another component in the distribution system (1).

We know of two simulation approaches developed to overcome the problem of piecemeal analysis of the total distribution system: the IBM software distribution system simulator (2) and Michigan State University's long-range environmental planning simulator (1). These simulators link the elements of production, warehousing, and customer demand; however, they do not provide a unified theory that quantifies the interrelationships of all the components of the distribution system.

A management consultant approaches the problem of warehouse location with the interest of minimizing the total cost or maximizing the total profit of the firm. With this in mind, he cannot afford to consider only certain components of the total distribution system, but he must encompass the entire scope of the problem and proceed to find a feasible solution (3).

A study of facility location errors by a loading consulting firm (4) identified the 10 most common faults in location, many of which occurred because of the failure to consider the interactions of the distribution system components.

LOCATION MODELS FOR DISTRIBUTION CENTERS

The following paragraphs will discuss and criticize the current theoretical and nontheoretical methodologies of location and distribution system analysis. The logical basis for developing, operating, and financing a unified freight distribution system in an urban area must be the consideration of warehouse location, which takes into account the other elements of the total distribution system. Eilon and Watson-Gandy (5) stressed the multifaceted character of terminal location problems, but their identification of the four fundamental components of a distribution system—number of terminals, location of each terminal, allocation of customers to each terminal, size of each terminal—is still quite incomplete, as will be shown later.

When theorists talk about the problem of locating distribution or collection centers, they implicitly assume an optimization objective. This objective is obviously only meaningful in relation to a measure or set of measures (criteria) to be optimized (e.g., minimum number of distribution vehicles, minimum total route distance, storage requirements, and manpower), subject to a number of constraints (e.g., access, land-rent, labor force, and legal and regulatory considerations).

Cooper (6) has stated the general problem in the following form: Given the location of each destination, the demands at each destination, and a set of shipping costs for the relevant area of distribution, determine (a) the number of distribution centers, (b) the location of each center, and (c) the capacity of each center.

The solution to this problem proved to be very difficult from both theoretical and computational perspectives. Consequently, other researchers have redefined the problem, changed the basic assumptions, and experimented with exact as well as heuristic solution techniques.

Mathematical approaches to this problem date back as far as 1647 when Cavalieri found that determining the point whose sum of distances from three given points is a minimum required that each side have an angle of less than 120 deg with the given minimum point (7, p. 332). Many of the recent approaches to the optimal location problems are based on or related to the generalization of the problem of determining the location of a point, in two-dimensional Euclidean space that represents the minimum distance or cost for a number of weighted destinations, as formulated by Weber (8). In mathematical terms the problem can be stated as follows:

$$\text{Min } \Phi = \sum_{j=1}^{n} \beta_j \left[(X_{Dj} - X)^2 + (Y_{Dj} - Y)^2\right]^{1/2}$$

where

X_{Dj}, Y_{Dj} = coordinates of known destination in two-dimensional Euclidean space, $j = 1, \ldots, n$,

X, Y = coordinates of unknown distribution point, and

β_j = weights relating to amounts to be shipped or any other weights.

The time required to solve all possible combinations of the generalized Weber problem is excessive except in cases where the problem involves very small numbers of terminals and destinations. Some authors have redefined the problem into a single source problem by subdividing the area of concern into several subareas each with its own source or terminal (9). For problems of industrial importance, heuristic solution methods, which incorporate a consideration of the customers to be served by each terminal, seem to provide the only answer to the multiple-source location problem (6, 10).

The solution approaches to the optimal location problem can appropriately be grouped into two categories (5): the infinite set approach and the feasible set approach. The first approach is based directly on the Weber model. Generally, these models are developed under the assumption that transportation costs are a linear function of distance. The objective function minimizes the sum of the weighted distances between sources (terminals) and destinations weighted by their demands. Solution of the optimal number of terminals is arrived at by establishing the optimal solution for 1, 2, 3 . . . terminals with respect to transportation costs (11).

The feasible set approach attempts to improve on the infinite set approach by (a) digressing from the assumption of linearity of transportation costs with respect to distance; (b) taking into account the overhead costs of a terminal that might be strongly affected by its specific location; and (c) considering the potential economies of scale in the operation of a distribution center.

Rather than consider all locations within a geographical space, the feasible set approach selects those locations that fulfill the following requirements:

1. The locations are feasible with respect to land availability, rental costs, and so on;
2. The operating costs for a terminal in such a location can be determined;
3. The absolute optimum set need not be in the solution set; and
4. Transportation costs need not be related to distance.

The objective of this approach is to determine the set of locations with minimum total cost from a preselected set of feasible locations (5).

The major shortcomings or difficulties with this latter approach are that subjective evaluation criteria will have to enter the selection process, that the problems of data gathering on all cost items can be tremendous, and that feasible set problems tend to become very large because of the greater number of constraints.

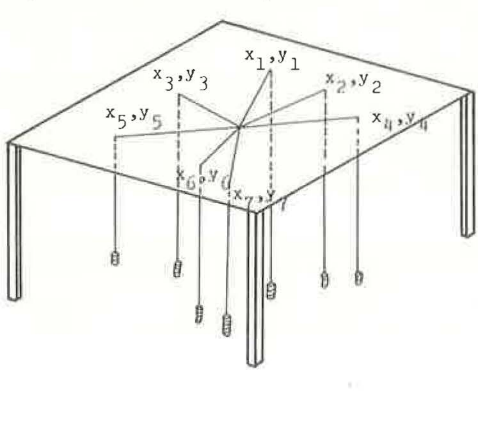
After reviewing and testing a number of solution strategies in each of these two approach categories, Eilon and Watson-Gandy (5) concluded that their "total cost model" of the feasible set type represents the most promising and efficient heuristic solution technique. Their model takes into account three cost items:

1. Transportation costs from production site to distribution terminal,
2. Local distribution costs, and
3. Warehousing costs.

Through an iterative procedure, the solution technique arrives at the lowest cost alternative for the depot locations. By using a so-called "drop-routine," the authors also determined the optimal number of terminals in the system. It should be pointed out that this approach does not pinpoint exact locations for the distribution center, but merely indicates the general area where suitable sites should be considered. A detailed benefit-cost analysis of any of these selected areas would be advisable to determine the exact optimal location of each distribution center. Naturally, this analysis would not look at optimality in a systemwide context but would concentrate on each terminal location in isolation from the others originally located in an optimal manner.

The majority of the models reviewed are static rather than dynamic. Vergin and Rogers (12) proposed that optimal locations for centers of economic activities could be determined by identifying the spot where the sum of the costs of transporting goods between existing source and destination points and the new terminal location is a minimum. This center-of-gravity concept is frequently used in attempts to determine the optimal location of distribution centers. Vergin and Rogers suggested several methods of solving the above problem. One method is the mechanical analogue (Fig. 1), which operates as follows: A map is secured to a table, and holes are drilled through the table at the customers' locations. Strings are passed through these holes with one end carrying a weight proportional to β_i (analogous to β_i in the generalized Weber model) and the

Figure 1. Mechanical analogue.



other tied to a small ring or washer. The ring will locate itself at a point of minimal potential energy, which is the position at which the transport costs are at a minimum (11)

There are several disadvantages to this method, one of which is that the mechanical analogue of the generalized Weber model is only able to locate one terminal at a time, which in the case of a multiterminal location problem requires a subdivision of the entire region into areas each being served by a single depot. This clearly appears to be a feasible solution. There is, however, no established method of dividing the region exactly, and this can produce suboptimal location. A second disadvantage is that there is no indication of transportation and facility costs at the location involved, and such costing must be calculated by some other means. A third fault is that it is very difficult to construct a large model that will have the accuracy required for an optimal solution.

The weighted arithmetic mean is a second approach used by Vergin and Rogers (12). In this procedure, the optimal location can be determined at the intersection of the weighted arithmetic mean of the points of demand along two orthogonal axes, where the demand points are the destination-origin of the tonnage of materials flowing to and from the facility to be located. It was pointed out that finding the weighted arithmetic mean coordinates is analogous to the center-of-gravity approach of a two-dimensional object in mechanics. An illustration using rectangular movement and straight-line movement (Pythagorean theorem application) was given to solve a single-facility location problem.

The rectangular movement was designed to minimize the sum of transportation costs, which can be expressed as

$$C = \sum_{i=1}^{n} W_i D_i$$

where

C = total cost of transporting goods,
D_i = distance between location point and the n known destinations,
$W_i = T_i V_i$,
V_i = weight or volume of goods, and
T_i = charge/unit of distance/unit of weight or volume.

Given a location designated as (X, Y), the distance to point $i(x_i, y_i)$ can be expressed as $|x - x_i| + |y - y_i|$. It can be shown that the median of a discrete set of points X_i is such that the sum of absolute directors from it $\sum |x - x_i|$ is a minimum, and $\sum |y - y_i|$ is also a minimum. Therefore C is a minimum when the coordinates of the location point are the median value above.

In the straight-line approach the movement in the x direction depends on the movement in the y direction. Distance between the location point and the demand point i can now be expressed as:

$$D_i = \left[(x - x_i)^2 + (y - y_i)^2\right]^{1/2}$$

It can be shown that this equation is convex, indicating that there exists a single global minimum for C.

The arithmetic mean method, when used to find the optimum coordinates (x, y), produces answers that may be quite removed from the optimal. This is due to the difference in the amount of tonnage at each destination. When the tonnage delivered to each destination is similar, the weighted arithmetic mean produces results close to the optimal location. However, as large changes in tonnage occur at destination points, the error in the process increases rapidly. Therefore, it can be concluded that not only are weighted mean coordinates seldom optimal when weighting factors for destination differ greatly, but they are not necessarily optimal when all delivery points are equally weighted (12).

Goldstone (13) suggested an iterative solution procedure to solve the straight-line problem. His method requires the selection of an efficient initial estimator (x_0, y_0). Goldstone proposed that, because Vergin and Rogers' square weighted start point gave costs closer to optimal, the possibility of higher powers might mean a quicker solution to the same result. An example of 24 warehouses serving two to 10 shops was tested, with results of higher powers yielding quicker optimal solutions.

A number of other solution strategies and techniques have been proposed that do not fit into the general framework of the two-category classification presented. Three examples of such approaches follow.

Eilon and Deziel (14) propose the use of a general-purpose analogue computer to solve the straight-line distance, single-facility location problem. If more than one distribution center is to be optimally located, the final solution depends on the initial choice of center locations and the subsequent allocation of delivery points (customers) to these centers. Using the examples of one center and 10 customers and two centers and four customers, they show that their results in terms of the value of the objective function are very close to those achieved by Miehle (15) obtained by an iterative analytical technique.

Eilon and Deziel assume linear transportation costs. If nonlinear transportation costs are assumed, a larger number of amplifiers would be required in the analogue computer. The method they describe can also be used to determine the optimal number of distribution centers for a given network.

Another approach to the terminal location problem was developed by Griffiths (16). His regression analysis approach deals with a distribution system that involves three distribution centers and a network of transit depots. He considers the delivery costs from transit depots to customers, which are divided into two categories: number of vehicles and drivers and mileage traveled by the vehicles. Griffiths' objective was to develop an estimate of the time required by a delivery vehicle to satisfy a certain demand.

To determine depot locations, he developed a route-independent measure of mileage. The run of the straight-line distances from each town to the depot produced the best results for such a measure.

Many studies of location have been performed in the context of optimal layout of manufacturing plants, large service operations, and department stores. An example of an approach that is applicable to the solution of both terminal location and layout problems was proposed by Curry and Skeith (19). They developed a dynamic programming formula to solve the problem of minimizing total cost when k facilities are allocated in m facility locations and n demands are assigned.

The typical context would be the most efficient way of arranging supply facilities with respect to fixed demand points in a manufacturing plant so as to minimize the travel distance between them. Both conceptually and computationally the approach presented in their work appears to be suitable also for use in determining warehouse locations if a number of specific sites are known as suitable alternative locations.

The authors formulate the problem as a nonlinear minimization problem that can be transformed into a dynamic programming formulation. Because the problem involves two decision variables in one of the constraint equations (namely two 0-1 variables indicating the allocation of a facility to a location and allocation of a demand location to a facility location), it is separated into a multistage optimization problem in which the stages, representing facility locations, are optimized sequentially. This problem is overcome by using the Lagrange multiplier technique and by including one of the constraint equations in the objective function.

Computationally this dynamic programming approach has the property that adding facilities or facility locations to the problem will only have an additive effect on the solution time as compared to an exponential (or fractional) effect for an exhaustive search method. The state space for each stage of the problem, however, is equal to the product of the number of fixed demand points and the number of possible facility locations. This latter aspect makes this approach impracticable for multiple-terminal location problems involving large numbers of demand points.

DISTRIBUTION OF FREIGHT

Analyses of the physical distribution of freight, from terminal to demand point, have produced algorithms that determine vehicle fleet routing under a variety of constraints and the set of demand points that are to be most economically served from a particular terminal. Also, the costing of physical distribution has received a great deal of attention recently in response to the precise data requirements of new cost models of the distribution process. The following sections will discuss relevant models and algorithms developed to analyze the distribution of freight.

The first mathematical fleet routing algorithm was developed by Dantzig and Ramser (20). The problem was to route a vehicle fleet from a single depot to a set of customers, which had individual, constant demands for a homogeneous commodity supplied by the depot, such that the total mileage of all routes is minimized. All customer demands must be satisfied and all fleet vehicles are assumed to have the same capacity C.

The authors noted that, if the capacity of a vehicle was greater than the sum of customer demands to be fulfilled from the depot, the problem reduces to the traveling salesman problem. Within this formulation, it is assumed that the vehicle can visit every demand point. Dantzig and Ramser, however, confined their attention to the case in which a vehicle cannot make all of the deliveries in one journey from the depot because of the capacity restriction of the vehicle.

The procedure of their algorithm is based on a series of N stages of aggregation in which suboptimizations are carried out. In the initial stage of aggregation, only those points whose combined demand does not exceed $(1/2^{N-1})C$ and whose interpair distances satisfy the criterion described below are allowed to pair up to begin a route. In the next stage any groups from the suboptimal solution of the initial stage may pair up provided that the combined demand of such pairings does not exceed $(1/2^{N-2})C$. This procedure is continued until N stages of aggregation have been examined.

In each stage minimum interpair distances are determined. These pairings of points or groups of points are the suboptimal solutions achieved in each stage. In the final stage the sum of route lengths is near minimum for all routes. This stage also links the ends of the chains formed to the depot. Every point is connected to no more than two points and this series of connections must form a "circular" chain with one of its links being the depot.

The authors noted that the algorithm could consider multiproduct demands, provided that, from the carrier's point of view, the goods are similar to each other (weight, volume) so that, regardless of the product mix, the vehicle could still accommodate the same number of units. Also, Danzig and Ramser suggested that, if a vehicle fleet of varying capacity was to be considered, the optimization function should be redefined as a total cost minimization rather than a total mileage minimization. The cost function would be composed of charges based on unused unit volume and unit mileage. The implicit assumption of the equal-capacity vehicle fleet is that slack capacity incurs no cost. With a variable-capacity fleet, effort should be made to use the differential capacity most efficiently by minimizing the unused space in each vehicle. This would imply, according to Dantzig and Ramser's methodology, that the vehicles should be loaded as fully as possible when they leave the depot, a philosophy practiced by many fleet managers.

Clarke and Wright (21) investigated the same problem except that they specifically considered a vehicle fleet of varying capacity. They observed that the Dantzig-Ramser algorithm caused delivery points that had been aggregated in a stage to remain aggregated in later stages. This produced a method that emphasized filling trucks to their capacity and only partially minimized total route distance.

In addition to their algorithm, Clarke and Wright produced a criterion for including a customer on a route (which evolved from Dantzig and Ramser's minimum interpoint distance)—the "route savings" criterion. Route savings is a measure of the priority, in terms of linear distance, of linking customers A and B to each other on a single delivery route, instead of having two out-and-back trips to serve A and B from the depot.

Distant customers are given priority in the route search technique because it is more economical to incorporate these outlying customers on one route than to serve them by more than the number of vehicles specified by this procedure. Isosavings curves are used to partition the set of customers according to sets of successively greater savings to be achieved by incorporating them on a multiple-delivery route (22). Computer routing would progress from the sets of greatest savings to those of least savings.

In their algorithm, pairs of points that would experience similar levels of savings are linked on a route if the following conditions are met:

1. The points are linked to the depot by a route,
2. The points are not already allocated on the same truck route, and
3. The additional demand requirement, which results in the removal of trucks allocated to serve the points in question and the allocation of a truck to serve the new augmented route, is not larger than the greatest capacity vehicle that has not yet been allocated to a route.

This approach, when subjected to the data considered by Dantzig and Ramser (20), produced routes with a total distance of 290 units. The algorithm of Dantzig and Ramser produced different routes that yielded a total distance of 294 units. Also the Clarke-Wright algorithm is far less involved computationally than the earlier method. The method of allocating trucks to routes does not ensure maximum capacity utilization; however, practical constraints on vehicle requirements may easily be incorporated into the formulation.

As Clarke and Wright point out, although the solution to their algorithm produces a sequence of customers to be serviced on a route, the traveling salesman problem should be solved for each final route to determine the true optimum order of visitation.

A flaw in this algorithm is that, once a link is established, its contribution to route minimization is never reevaluated; the link remains a part of the route even if a series of future links would have rendered the choice of this particular link inappropriate. This argues for a dynamic programming formulation of the vehicle routing problem.

Gaskell (22) also considered the problem as stated by Dantzig and Ramser with the additional constraint that total mileage of any route may not exceed a specified limit. Essentially, Gaskell sought to determine a simple, near optimal method for fleet vehicle routing. He compared five methods for determining whether a customer should be included on a route. The first method was a manual search of all possible routes within the artificially developed cases. This search was extensive and was considered optimal. The remaining four methods were variations of the route savings criterion. The mathematical property of these variations is that they altered the order or priority in which demand points are considered for linking on a common route. Gaskell determined that no particular method was superior in all cases and that the method suggested by Clarke and Wright for vehicle routing was reasonable.

Christofides and Eilon (23) proposed an "r-optimal tour" method to route vehicles where the problem is the same as considered by Gaskell. The origin of the r-optimal tour method lies in two properties of the minimal traveling salesman tour: Such a tour does not intersect itself, and the tour that does not intersect itself is one that cannot be reduced in length by replacing any two links by any other set of two links. This latter property is known as a 2-optimal tour. The same principle is extended to form a 3-optimal tour.

Although the 3-optimal tour could be extended to an r-optimal tour, as r approaches n (the number of points to be served on a route), checking sets of links becomes a complete enumeration of all possible tours to that group of customers. The authors determined that a 3-optimal tour produces good results.

The algorithm proceeds as follows. An arbitrary random tour that is feasible (i.e., it satisfies all constraints) is developed. A 2-optimal tour is generated, and the improved tour is then used as the basis for forming a 3-optimal tour. The procedure is repeated several times (i.e., a different set of customers is incorporated into the initial tour, given the constraints) and the most improved (least cost) tour is selected. This procedure does not necessarily minimize the number of vehicles required to supply the customers.

Christofides and Eilon noted that, although the general routing problem can be formulated in a dynamic programming structure (24) or as an assignment problem in integer programming (25), the computation time and storage demands become excessive for large problems.

O'Neil and Whybark (26) compared the efficiency of five routing heuristics that were computationally simple. Only two of the formulations proved uniformly near optimal: the route savings method and the clustering and travel time saved heuristic. The latter method was developed from the statistical concept of clustering analysis. Customer groups are formed on the basis of customers' proximity to one another in terms of travel time. A cluster is chosen so that the demands of the customers cannot be served by a single visit to that cluster by a vehicle. This is done to ensure that the first vehicle will not be assigned to a route that underutilizes its capacity. The route savings method is then applied to members of this cluster. This procedure iterates and redefines new clusters as routes are established. The heuristic works well when customers are clustered naturally. The clustering of demand points is an observed phenomenon in many real-world situations.

Vehicle routing, as Higgins (27) suggested, can be accomplished by simple, nonalgorithmic models when the fixed and variable costs of freight distribution can be identified. These costs can be used to determine variable costs that are then applied to a series of Monte Carlo simulations of deliveries of a particular commodity to demand points or clusters from a depot. The route simulation that yields the least total cost routing policy is adopted as the routing strategy.

Many depot locations have been determined by the analogue machine approach to solving the generalized Weber problem. This approach does not assume that there will be out-and-back delivery routes, but rather that the cost of the eventual routes will vary linearly with distance of the customers from the depot. There is a discrepancy between the minimized radial distances generated by solving the generalized Weber problem and the actual distances traveled by vehicles dispatched from the depot to serve customers. This difference is accentuated because, in practice, deliveries to more than one customer on a single trip from the depot are common. Christofides and Eilon (23) computed from a series of 42 randomly generated problems a regression equation of the actual distance traveled as a function of the radial distances. They noted that the relationship indicated a high degree of correlation and that the position of the depot with respect to the customers, which was varied in several problems, did not significantly alter the strength of the relationships.

Most distribution studies consider the location of the terminal to be fixed. If there is a cost trade-off between serving a portion of the customers' demands by the corporate fleet and making deliveries by using alternate distribution services, geographical boundary areas within which it is most economical for a firm to use its own vehicle fleet for distribution should be established for the terminal. Buxton and Quayle (28) suggest a method for determining boundary areas, for a fixed warehouse location, that delineates the economical regions for the firm's fleet and common carrier distribution. Two constraint boundary lines are developed. The time constraint boundary line determines the geographical area a vehicle may service in a day. The available number of driving hours per day, average miles per hour per zone, ratio of the furthest peripheral point in miles (i.e., greatest diameter of the route) on a route, and the total mileage of the route are the informational requirements necessary to compute this boundary. The cost equalization boundary is the set of points at which the cost difference between fleet and common carrier distribution is zero. This boundary equation requires measures of fleet distribution, costs per mile and per ton, current average route mileage, and market demand in tons per square mile in the study zones. The innermost boundary curve (with respect to the depot) defines the delivery area for the depot.

Certain distribution situations require the fleet to make deliveries to demand points, which vary from day to day. In this situation, Christofides (29) suggested that fixed areas for distribution instead of fixed routes should be established. The fixed area for distribution is the nearest approximation to the fixed route for the situation of variable demand. An algorithm similar to that used to generate fixed vehicle routes is used to successively build up delivery areas from the basic areal units defined by customer locations.

The determination of depot delivery areas constitutes an extension of vehicle fleet routing methods where an extra degree of freedom, in terms of vehicle fleet operation, is incorporated.

EVALUATION AND PRACTICAL APPLICATION OF DISTRIBUTION MODELS

Throughout this paper both location and distribution models have been discussed to determine the feasibility and applicability of these models in describing and analyzing the operation of the entire distribution system. Shortcomings of the particular examples used were cited. We will now take a closer look at these shortcomings and comment on their influence on the analysis of the complete system.

Distribution system analysis is characterized by cost functions that fail to develop accurately the total costs of distribution processes. Specifically, in both the theoretical and practical approaches to distribution system analysis, the costs that are generated by physical distribution are not well understood or fully identified. This situation has resulted in the use of oversimplified, noncomprehensive cost functions, which can produce serious errors (30) if they are incorporated in a location or distribution analysis. The following important cost factors are commonly misunderstood.

1. The ton-mile statistic is used as a transport cost statistic when it is intended to measure only transportation work. A ton-mile statistic forces equal weighting of the ton and the mile. Many location models, especially gravity formulations, are based on statistics of this type.
2. Transportation costs vary nonlinearly with distance, except when carriers are constrained by regulation to operate under fixed rates.
3. In practice multiple deliveries occur, and a customer may be served on that particular trip if sufficient vehicle capacity exists. Otherwise the demand point must wait to be serviced by another vehicle. This "combinatorial" element of cost (30) indicates that inclusion of shipment size and demand point location only would result in an incomplete cost function.

An early case study of a distribution system (10) did not give adequate consideration to many cost factors. These misunderstood factors, including the three mentioned previously, were used in siting a pair of factories.

The use of a simple function to describe distribution costs is characteristic of the approach to the problems of warehouse location and distribution analysis taken by operations research people. Managers of firms that accomplish their own physical distribution are vitally interested in the complex of costs ascribable to the distribution system. Costs associated with warehousing and inventory are allocated and recorded far more comprehensively and accurately than those costs associated with the actual physical distribution of freight (31).

Also, most operations research approaches to distribution system analysis tend to ignore the complex interactions of the firm's various organizational units that effect physical distribution. A particular example is the assumption of many operations research location models that customer demand is fixed. Notably, these models consider the short-run situation that deals with a fixed set of demands in locating the warehouse, which is a long-term facility (32).

According to Christopher and Wills (33), the total cost concept or the "total logistics" concept is probably the most important concept in physical distribution management. The total cost is as follows:

$$\text{Total cost} = F + I + T_1 + T_2$$

where

F = fixed costs of warehousing,
I = stock holding cost,
T_1 = cost of trucking, and
T_2 = cost of local deliveries.

This principle is well indoctrinated into most firms, but there is little effort to apply this idea in practice (34). Even though distribution is the link between the production and marketing of a product, decisions made without consideration of distribution (e.g., all deliveries made within 48 hours upon receiving the order) will cause an unbalanced cost condition.

Figure 2 (33, p. 214) shows the general relationship of the components of the total cost equation. The curves are not strictly continuous or accurate in shape. They do, however, indicate how the costs behave in relation to an increase in the number of warehouses within the system.

Hoch (4) indicates that, in retrospect, many executives admit that the original decision to locate was made primarily on the basis of freight cost comparisons with no detailed study of rentals, payrolls, taxes, insurance, or inventory carrying costs, where these cost factors actually complete the fixed cost of warehousing.

With this background, changes in the components imply that T_2 would be minimized by establishing a warehouse at every customer's location. Similarly I can be minimized by having a zero inventory, which would result in disastrous serviceability. Therefore, given the possible factors of cost reduction and their implications, it becomes clear that the true minimum cost is the one that minimizes the sum of all costs. This has particular impact as Bowersox commented (1).

Minimizing cost has been the prevailing goal of the models reviewed. However, it must be pointed out that all the authors reviewed had a different concept of what cost should be minimized. As previously discussed, these models can be categorized as either the infinite set approach or the feasible set approach. The main disadvantage of the former is that the method requires that the transport costs be directly related to distance, which is not a valid assumption in all cases. The main disadvantage of the feasible set approach is that not only is a considerable amount of effort and expense involved in building a list of sites and their costs, but also in a changing situation available sites may not be known (33). The models presented consider only cost items relating to weights, destinations, positions, and transportation costs, the sum of which is not the total cost of a distribution system.

The factors determining the location of distribution centers vary substantially from place to place. One is well advised to keep in mind those locational factors that are most important in practical locational decisions. Table 1 gives the decisive factors used in locating truck terminals in the Hall Street area of St. Louis, Missouri. The outstanding feature of this table is the fact that land availability clearly outweighed the

Figure 2. Total cost and component curves.

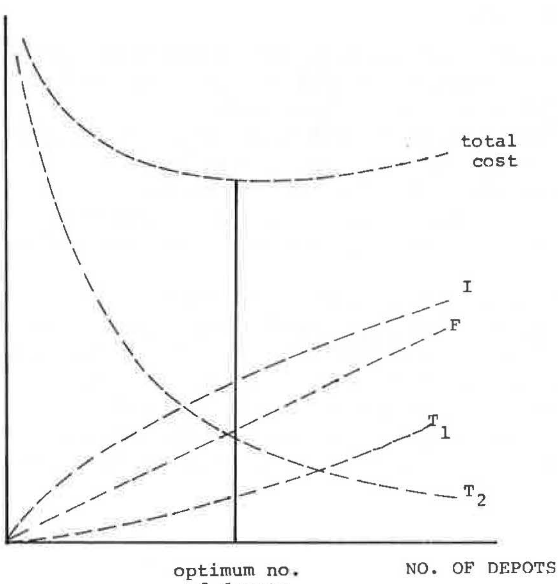


Table 1. Truck terminal location factors (35).

Factor	Percentage of Respondents Considering Factor Most Important
Land availability	81
Proximity to other carriers	35
Proximity to shippers and consignees	27
Cost of land	23
Access to major highways	23

other factors by a substantial margin. The fact that the location of truck terminals has moved outward from the central city supports the importance of land availability, in addition to other locational decision factors. Schwar (36) has documented this latter development in the Chicago metropolitan area for the period 1950 to 1960.

Hoch (4) analyzed the typical mistakes made in warehouse location. His study was based on observations and reports from more than 1,000 U.S. manufacturing corporations. The main point of his analysis is the fact that, when asked "Has your warehouse location been completely successful and, if not, what have been the most important problems?," the following were the most frequent answers given (in descending order):

1. Failure to consider total costs,
2. Carelessness in checking site,
3. Failure to anticipate growth,
4. Underestimating the importance of taxes,
5. Miscalculating labor costs,
6. Inadequate labor reservoir,
7. Lack of supporting facilities,
8. Lack of distribution know-how,
9. Location by imitation or compromise, and
10. Incorrect cost relationship.

Although there was no indication of the percentage of companies dissatisfied with their operation, it is clear that the problems cited above are not part of the data considered throughout the literature on location and distribution.

The elaboration of each of the above indicates that there is a great fallacy in the premise that location and distribution can, indeed, be thought of as a linear operation.

Demczynski (37) believes that the most important single factor that results in such mistakes, as listed above, is the lack of communication between the mathematicians and the line executive. He indicates that mathematicians fail to explain their work in terms that the nonspecialist can understand. The line executives are often suspicious of the methods proposed because they do not fully understand what is proposed and because they carry the responsibility for implementation and results. The magnitudes of the proposals are startling to the executives, and they are not willing to place their reputation on something they do not fully understand. As previously mentioned, heuristic methods appear to be the most reliable techniques to employ in solving the many-faceted location problem.

CONCLUSIONS

This paper has attempted to provide the informational base for evaluating the present capability and applicability of techniques, methods, and models for analyzing distribution system structure. It was determined that no universally accepted and suitable technique or theory exists at the present time. This resulted in the necessity for presenting and evaluating a variety of research efforts documented in the literature. It can be concluded that serious faults underlie component-by-component analysis of the distribution system. This approach is questionable because the performance of the whole system is the decisive element in the functioning of a distribution system and not the individual operation of its components.

Real-world problems are of such a nature that many components must interact. Piecewise analysis is characterized by analytical methods that deal with the components only within their own structure. Optimality is reached within the operation of the individual components but rarely in the context of the whole system-suboptimization.

Clearly, research should be initiated to develop techniques and methods that specifically express or quantify the component interactions typically encountered in real-world problems. Emphasis should be placed on developing a manageable distribution system-warehouse location theory.

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MEASUREMENT OF URBAN COMMODITY MOVEMENTS

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An analytical framework for summarizing small commodity movements within an urban area is described. This methodology for measuring urban goods movements consists of a series of operations that process data on commodity shipments and the activity system to provide an input-output summary of selected urban commodity flows. Initially freight service zones are established for the study area, and classification systems are developed for commodity flow origins and destinations and for categories of small commodities. Commodity movements are represented in terms of temporal, volumetric, and spatial dimensions to show variations in demand for commodity transport. Relationships are then developed between commodity demand (flows) and activity units to establish the input-output model. The resulting information aids the development of a forecasting methodology of the demand for urban goods movements. The areal flow measures are analogous to the outputs of the distribution phase of the urban transportation planning process and, accordingly, give loadings that can be simulated on alternative delivery system designs to render measures of performance for evaluative purposes. A direct firm-based commodity shipment survey procedure is recommended to obtain the essential planning data currently lacking on goods movements.

• THE TRANSPORTATION of goods within an urban area is a costly operation. A recent article on the problem (1) stated that the cost of local delivery is about eight times that of local people movement by public transport and that 40 percent of the total national freight bill is consumed by this phase of distribution. On the same subject, the Tri-State Regional Planning Commission has estimated that $95 million could be saved annually if all New York metropolitan area pickup and delivery operations were coordinated.

A major segment of intraurban goods movements, which is the subject of this paper, is the small shipment weighing less than 500 lb. Technological improvements in the local collection and delivery of small shipments would considerably reduce total goods transport costs. The evaluation of improvements to local goods transport is very difficult because there is a lack of adequate data on local freight movements and, hence, little understanding of local delivery requirements. In most cases, the information on hand specifies the origins and destinations of goods movements relative to individual means of transport and is thus means specific (2). [Means is used to include measures of service that reflect distinctions in characteristics of the truck mode and methods of handling various commodities (4).]

The objective of this paper is to develop procedures for measuring local goods movements that will show how various fragmented deliveries can be collected and consolidated so that ultimately a coordinated local delivery system providing required levels of service and reduced costs can be developed. This methodology could be used to study use of urban transit for goods delivery during off-peak hours. The need for descriptive measures of local goods movement is particularly evident in this case inasmuch as the concept has been widely discussed, but it has been impossible to measure potential merits without knowledge of the actual loads imposed on the system.

The framework developed to measure and monitor urban goods movements consists of the following phases:

1. Establishment of freight service zones (in study area),
2. Classification of commodity flow origins and destinations,

3. A small commodity classification system,
4. Commodity demand characteristics,
5. Relationship between commodity demand (flows) and activity, and
6. Synthesis of land use and commodity systems (input-output model).

FREIGHT SERVICE ZONES

To properly define urban goods movements in a spatial perspective requires that a proper interface be established with the land use-activity system. Inasmuch as personal travel analyses use traffic zones for a frame of reference, a similar frame of reference is necessary for commodity movement study. Whereas in the former context traffic zones are established over a study area to reflect homogeneous centers of activity, the freight service zone represents an areal tract that exhibits uniform commodity-shipment needs among its constituent units. With these zonal bases it is possible to assess general trends indicative of generators of urban freight traffic.

The freight service zone is established in view of the major economic commodity flow generator categories (at an urban, small shipment level) listed below.

Origin	Destination
External	Wholesale
	Retail
Wholesale	Institutions
	Retail
Retail	Institutions
	Residential

With these classifications, a rudimentary system of freight service zones is derived in view of homogeneous conglomerations of the following activities: external (dummy peripheral terminal), wholesale, retail, major institutional development (e.g., offices, universities, hospitals, and governmental agencies), and residential.

In many respects this classification scheme for zonal land use is sufficient to specify a complete zonal system. However, the typical service zone system should be finalized in terms of zonal size and intensity of commodity movement. For example, a retail zone is conceivably much smaller geographically than, say, a residential area, for the former will exhibit a higher intensity of movement per developed acre. The breakdown of large retail and residential centers is based on the following considerations: intensity of flow, homogeneity of flows, access links to transport network, and vehicular or system capacity.

CLASSIFICATION OF COMMODITY FLOW ORIGINS AND DESTINATIONS

Each economic unit that serves as a terminus of goods flow (i.e., business or household) is referenced to the service zones and classified according to the coding system given in Tables 1, 2, and 3 to indicate the type of site development (building structure and type), major activity (store, office, etc.), and explicit economic function (3).

SMALL COMMODITY CLASSIFICATION SYSTEM

In this stage, an array of small commodity types is selected and classified to provide a framework for coding, aggregating, and processing data on urban small goods movements. This classification commodity listing given in Table 4 is derived from those used in the Standard Industrial Classification Code of the U.S. Bureau of Budget and Transportation Commodity Classification of the Bureau of Census. Although the code uses indexes different from those used in the major source codes, a direct correspondence can be established between them if desired.

COMMODITY DEMAND MEASURES

Measures that characterize the typical consignment of a given goods movement between certain origin-destination types must be established. In this initial investigation

Table 1. Classification of site adaptation.

Code	Class
00	No structure or nonbuilding structure
10	Office and bank building
22	One- or two-story factory or warehouse building, not fireproof
24	One-story factory or warehouse building, fireproof
25	Multistory factory or warehouse, fireproof
27	Specialized laboratory building
31	Produce warehouse
33	Rail and truck transfer shack
34	Refrigerated warehouse
35	Small one-story distribution warehouse
36	Large-area, single-floor distribution warehouse
37	Trucking terminal dock building
38	Wharf and dock shed
41	Free-standing one-story store building
42	One-story store building in a row
43	Single supermarket building
44	Supermarket complex
45	Multistory department store building
46	Two- or three-story building, store and residence overhead
47	Two- or three-story, store and office overhead
48	Two- or three-story building, store and loft space overhead
51	Residential buildings, single-family houses
57	Apartment building, 1 to 4 stories
58	High-rise apartment building or hotel
59	Dormitory building
61	Theater building or movie house
62	Sports area
63	Church building
64	Concrete hall
65	Bowling alley
67	Terminal building (air, rail, bus)
68	Stadium
71	Hospital building
72	Medical clinic building
73	School building
74	Museum or library building
75	Fire station
76	Police station
88	Motel building

Table 2. Major activity index.

Code	Class
00	No activity
01	Office activity, public oriented
02	Office activity, non-public oriented
04	Store activity
05	Shop activity
07	Eating and drinking
08	Residential, multiple-unit dwelling
10	Play and active recreation
11	School activity
12	Mass assembly and spectatorship
13	Passenger assembly
14	Other forms of public assembly

Table 3. Economic "over use" (function).

Code	Function
10	Residences
20	Finance, insurance and real estate
50	Wholesale trade
52	Retail trade, hardware
54	Retail trade, food
55	Retail trade, automotive
56	Retail trade, apparel and accessories
57	Retail trade, furniture, house furnishings, and equipment
58	Retail trade, eating and drinking places
59	Miscellaneous retail trade
60	Department stores
61	Mail-order houses
62	Limited price variety stores
63	Drug stores and proprietary stores
64	Merchandise vending machines
65	Dry goods, fabric and yarn
70	Hotels, rooming houses, camps, etc.
71	Laundries, dry cleaning, tailors, clothing rental
72	Photographic studios
73	Beauty shops
74	Barber shops
75	Duplicating, blueprinting, photocopying, stenographic services
76	Miscellaneous repair services
78	Motion pictures
79	Other amusement and recreational activities
80	Medical and health services
81	Legal services
82	Engineering and architectural services
84	Accounting, auditing, and bookkeeping services
85	Research development and testing labs
86	Advertising
91	Federal government
92	State government
93	City government
94	County government

into the problem, three basic flow dimensions are considered: temporal, volumetric, and spatial measures.

Temporal and Volumetric Characteristics

The demand for goods transport is assumed to derive from the characteristics and operational policies of shippers and/or receivers of the goods. It is further assumed that "routines" or goods delivery patterns develop that reflect repetitive scheduling over an appropriate time period (e.g., day, week). Also, different shippers and receivers exhibit different goods demands in view of goods types and characteristic shipment sizes. For example, business and household shipment ends will exhibit different consumption demands. Thus average measures for the temporal and volumetric dimensions of a typical goods consignment are applicable only to specific shipper-receiver combinations.

These observations are summarized by the following relationship:

$$F_j^{klT} = f(O_k,\ D_l,\ C_j,\ T) \tag{1}$$

where

F_j^{klT} = a measure of the flow of good j between origin type k and destination type l during time period T,

O_k = characteristics of freight shipment origin (firm),

D_l = characteristics of freight shipment destination (firm or household), and

C_j = commodity type.

Equation 1 gives the volume of flow of a specific good between a given origin-destination set over a certain time period (e.g., day, week).

This relationship can be used to show the temporal variation of a commodity flow during any period of time. For example, for T = 24 hours,

$$F_j^{lkT} = \sum_{t=1}^{24} F_j^{klt} \tag{2}$$

for i = 1, ..., 24 and where t indicates each hour during the day.

This formulation can also be taken to give the total flow of goods between any pair of activity units (k, l), the total flow of good j in the region, and the total freight received or sent from a particular place as follows:

$$F^{klT} = \sum_{j=1}^{P} F_j^{klT} \tag{3}$$

$$F_j^{T} = \sum_{k}^{M} \sum_{l}^{N} F_j^{klT} \tag{4}$$

$$F^{lT} = \sum_{j}^{P} \sum_{k}^{M} F_j^{klT} \tag{5}$$

$$F^{kT} = \sum_{j}^{P} \sum_{l}^{N} F_j^{klT} \tag{6}$$

where

P = number of commodities considered,
N = number of shippers, and
M = number of receivers.

Spatial Characteristics

The spatial characteristics of urban goods movements are assumed to be dependent on the corresponding shipper-receiver set and the commodity class. The total areal demand for a product will give an indication of the number of shipping firms involved. The number of shippers is assumed to be relatively small compared with the population of receivers (consumers), and each shipper is concerned with a given market area. The distribution of delivery trip lengths is then a function of a seller's viable market area. In the case of multiple sellers, this conceptualization becomes complex as shown in Figure 1. A model at this stage must therefore be sensitive to the market relative to

1. Location of sellers,
2. Location of receivers,
3. Areal product demand,
4. How competitive each firm is relative to the other,
5. Brand advantages, and
6. Economic self-containment of subareas.

The proposed analysis of market areas is based on data on the deliveries and locations of a firm's customers (information on both carried and delivered goods is required). Because many businesses provide sales receipts, it is feasible to proceed in this manner. An example of the output of this phase is given in Table 5 as a frequency distribution of goods movements according to distance. The amount of product j originating at firm k, shipped to destination l during period T, and traveling distance s is

$$F_j^{k T s} = F_j^{k T} f_j(s) \tag{7}$$

and the average distance that shipments of commodity j are transported within the study area is

$$\bar{S}_j = \sum_{w=1}^{W} s_w f_j(s) \tag{8}$$

where W = total set of discrete trip length intervals.

GOODS FLOW AND O-D ACTIVITY MAGNITUDES

The development of a mechanism for relating goods flow measures with certain O-D activity linkages is now considered. The subscript j is assigned a digital value to correspond with the commodity code given in Table 4. Specific O-D types are examined to establish sets of common desire patterns. The k and l superscripts previously used to indicate an O-D pair are replaced by generalized characteristic vectors Z_o and Z_d, which are derived from the site adaptation measures given in Tables 1, 2, and 3.

$$\begin{aligned} Z_o &= [SA_o,\ AI_o,\ EF_o] \\ Z_d &= [SA_d,\ AI_d,\ EF_d] \end{aligned} \tag{9}$$

where

SA = site adaptation code,
AI = major activity index,
EF = economic function,

Table 4. Group and item descriptions of major commodity groups.

Code	Group Description	Item Description
0	Mail	
01		Letters, U.S. Postal Service
02		Packages, U.S. Postal Service
03		Courier, private delivery
1	Food and kindred products	
10		Food and kindred products
11		Baked goods
12		Beer, wine, alcoholic beverages
13		Tobacco
2	Laundry, dry cleaning, etc.	
20		Laundry, dry cleaning, etc.
3	Printed matter	
30		Newspapers
31		Books, magazines
32		Other printed matter
4	Building furnishings, equipment, and appliances	
40		Furniture and home furnishings
41		Floor coverings
42		Electrical appliances
43		Housewares
5	Building operation, equipment and improvement items, automotive items	
50		Automotive
51		Paints
52		Glass
53		Hardware and home repair items
54		Plumbing and heating
55		Airconditioning and refrigeration
6	Apparel and accessories	
60		Apparel and accessories
61		Fabrics, yarn, thread
62		Footwear
63		Jewelry
64		Leather goods
65		Optical goods
7	Office supplies and equipment	
70		Office equipment
71		Paper products
72		Equipment and supplies for service establishments
73		Professional, scientific, and controlling instruments and supplies
8	Drugs	
80		Drugs, cosmetics, etc.
9	Recreation equipment and gift items	
90		Toys and amusement goods
91		Sporting goods
92		Flowers, florists
93		Nursery products
94		Religious goods
95		Music
96		Bicycles
97		Cameras and photographic supplies

Figure 1. Competition among firms for a market.

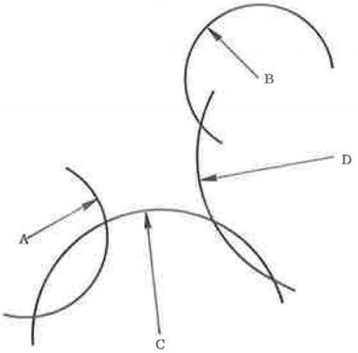


Table 5. Spatial market for firm k, product j.

Distance Category	Distance, s (miles)	Frequency of Occurrence, $f_j(s)$ (percent)
1	$0-\frac{1}{4}$	12
2	$\frac{1}{4}-\frac{1}{2}$	10
3	$\frac{1}{2}-1$	22
4	1-2	10
5	2-4	30
6	4-8	10
7	7-10	6

Z_o = origin characteristics, and
Z_d = destination characteristics.

The generalized commodity flow variable now becomes

$$F_j^{Z_o Z_d T s} \quad (10)$$

which equals the volume of flow of good j between firms o and d during time T and spatial separation s.

If categories for shippers and receivers are established relative to some production surrogate (i.e., employment or floor space for commercial units and population density for residential areas), a unit activity measure can be defined for each category. This unit measure is then a lower limit on the resources required of a firm to be engaged in the distribution of a certain commodity. Thus, if $F_j'^{Z_o Z_d T s}$ is the unit measure relative to Eq. 10, then, for specific O-D combinations, this value can be scaled according to a potential ϕ, which is defined as

$$\begin{aligned} \phi &\sim (E_o, P_d, R_{od}) \\ \phi &= kE_o^{\alpha} P_d^{\beta} R_{od}^{\delta} \end{aligned} \quad (11)$$

which equals goods per period per unit measure where

R_{od} = a generalized travel impedance factor,
k, α, β, δ = constants of calibration,
E_o = employment at origin firm, and
P_d = population density at destination zone.

$$F_J^{Z_o Z_d T R_{od}} = \phi F_J'^{Z_o Z_d T R_{od}} \quad (12)$$

subject to ϕ = 1 where

$$F_J^{Z_o Z_d T R_{od}} = F_J'^{Z_o Z_d T R_{od}}$$

Equations 11 and 12 are then commodity flow generation and distribution measures.

AREAL SUPPLY-DEMAND CONCEPTS

The interzonal commodity flows for an urban area are summarized by a matrix based on the following considerations.

1. A list of supply nodes for each commodity,
2. A list of supply quantities for each node,
3. A list of demand nodes for each commodity, and
4. A list of demand quantities for each node.

These ideas are shown in Figures 2 and 3 and are summarized by the following measures.

$$V_J^K = \sum_I F[K, I, J] \quad (13)$$

where

V_J^K = quantity of good J originating at zone K (supply),
J = commodity index,
K = origin zone,
I = industry index, and
F[K, I, J] = quantity of good J originating at zone K from industry I.

A similar relationship can also be shown to hold for the demand nodes. Here F[L, I, J] represents the demand for good J by industry I located in zone L.

Figure 2. Supply summary.

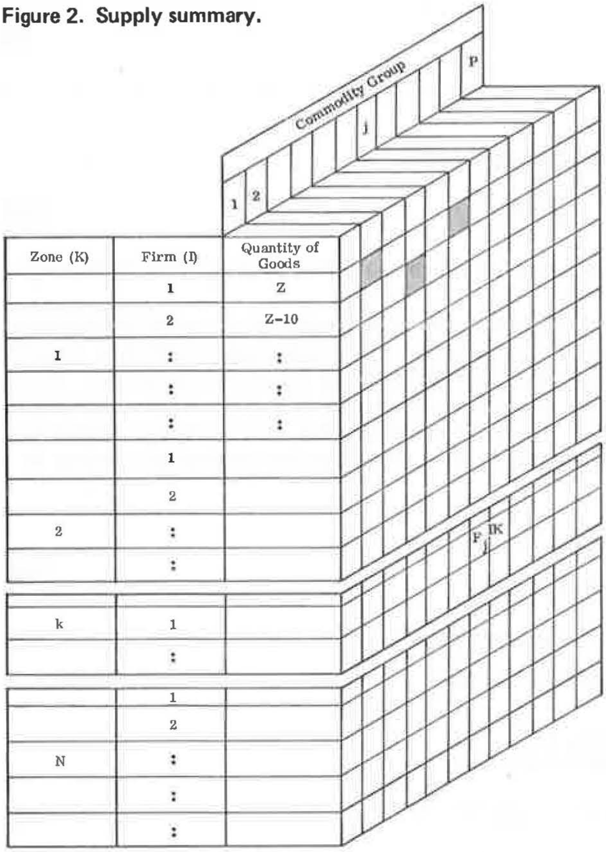
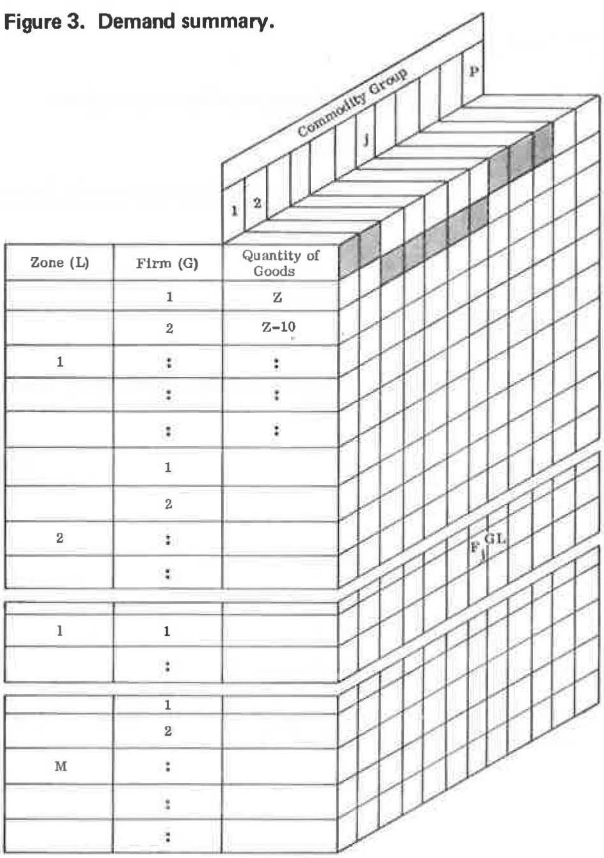


Figure 3. Demand summary.



$$D_J^L = \sum_I F[L, I, J] \quad (14)$$

SYNTHESIS (INPUT-OUTPUT MODEL)

The supply and demand information shown in Figures 2 and 3 is now synthesized by an interaction matrix given in Table 6. This table is directly related to the summary computations previously developed. If we neglect the time stratification, the entries into each cell of the commodity flow matrix are the flows of a given good j from industry I in zone K to industry G in zone L. Thus, this quantity is represented as F^{IKGL}, which has the following correspondence with Eq. 2.

$$F_j^{kl} = F_j^{IKGL} \quad (15)$$

where

k, l = firm indexes,
I, G = zonal firm indexes, and
K, L = zonal indexes.

The association with Eqs. 3 through 7 is similar.

The travel distance factor, $f_j(s)$, or more conveniently a travel impedance factor $f_j(R)$, which derives from a number of travel cost factors such as time, cost, and frequency, is given in Table 7 to show the zone-to-zone (K to L) impedance measure (R_{KL}). If, for example, $R_{KL} = s_{KL}$ (distance), then each row in Table 7 can be taken to give a distance frequency distribution like that given in Table 5. The same can be done columnwise to show the distribution of travel distance for goods received. Equations 7 and 8 are thus satisfied.

The methodology derived provides the operations necessary for processing commodity data (Table 6) with the transportation (Table 7) and activity (Table 8) system measures to show specific goods flow channels, $F_j^{Z_oZ_dTR_{od}}$, relative to the characteristics of shippers and receivers, time periods, and transport impedances. Once a basic data file is created, various generalizations and relationships such as proposed in Eqs. 11 and 12 can be investigated to establish the postulates necessary for the development of a demand forecasting methodology for urban goods movements.

APPLICATION

The given methodology has been designed to summarize intraurban goods movements relative to a set of firms (wholesale, retail, households). The basic output provides measures of commodity flows in an urban area to and from specific shippers and receivers. The mechanism is provided for various degrees of aggregation such as interzonal flows or flows among firms or groups of firms.

To implement the methodology requires only firm-related data. In other words, because the objective was to measure goods movements, carrier data sources were assumed to be of secondary importance. The required activity data then include specification of freight service zones and inventory of significant firms with appropriate statistics on each, and the necessary goods movement data include, for each wholesale and retail firm of interest, documentation on each freight arrival and shipment during a specified time period (which must be assumed as repetitive in a cyclic fashion). With these selected data, it is envisioned that local destinations as well as out of town origins for the majority of goods movements will be obtained. Interfirm flow can be used to verify the data.

This information appears sufficient to specify current goods movement in the urban area. The counterpart in urban passenger transportation planning is the output of trip distribution. Once this task is accomplished, the given freight movements can be loaded on various alternative delivery systems and simulated to give measures of performance. These data requirements are given in Tables 9 and 10.

Table 6. Commodity flow interactions.

From	To D[L, G, J]			
V[K, I, J]	111	112	L G J	NMP
111				
112				
113				
121				
211				
212				
KIJ			F_J^{IKGL}	
NMP				F_P^{MNMN}

Table 7. Travel impedance matrix.

L / K	1	2	3	4	1	n
1						
2						
3				R_{34}		
k					R_{k1}	
n						

Table 8. Zonal inventory data.

Zone K	Number of Different Industries	Industry KI	Activity Intensity Measure P.., E..	SA AI EF
1	5	11	E_{11}	
		12	E_{12}	
		13	P_{13}	
		.	.	
		.	.	
		.	.	
2	1	21	P_{21}	SA AI EF
.	.	.	.	.
.	.	.	.	.
n	2	n1	E_{n1}	SA AI EF
		n2	E_{n2}	

Table 9. Local firm data.

Data Entry	Class: Retail	Wholesale[a]	Institution	Household[b]
1. Firm number	R-	W-	I-	Zonal No.
2. Location	Zone	Zone	Zone	Zone
3. Site adaptation	SA	SA	SA	SA
4. Major activity	AF	AI	AI	08
5. Economic "over use"	EF	50	EF	10
6. No. employed or population	E	E	E	P
7. Gross annual sales	AS	AS	N/A	N/A
8. Annual income or budget	N/A	N/A	B	I
9. Major commodities handled	C	C	N/A	N/A

[a]Includes distributors and manufacturers.
[b]Household measures aggregated in terms of residential zone statistics.

Table 10. Typical commodity shipment data (from retail and wholesale entries).

No.	Shipping Data	Value
1	Shipper or receiver (source firm)	0 = shipper; 1 = receiver
2	Means of transportation	
3	Destination	If 1 = 0
	Origin	If 1 = 1
4	Commodity type	From Table 4
5	Quantity	Lb, number, etc.
6	Distance	Total O-D travel distance
7	Time of departure or arrival	
8	Type of service	Single or multiple commodity
9	Repeat 3 through 7 for all entries if multiple commodity	

SUMMARY

This paper provides a new strategy for analysis of urban goods movements. It is the initial step toward an important objective: development and implementation of an analytical framework for comprehensive analysis and evaluation of innovative solutions to the local delivery problem.

Even though the model is derived from comprehensive considerations, the procedures for measurement of urban goods movements given below are straightforward:

1. Establish zones,
2. Inventory firms and select representative subset for shipment survey,
3. Survey shipment,
4. Process data,
5. Prepare interaction matrix,
6. Prepare interzonal impedance matrix, and
7. Analyze and test causal relationships.

The operational tasks involved concern data processing and manipulation, inasmuch as the goal is to describe existing patterns of urban goods movements. The summary mathematical relationships, which have been given as directing the methodological development, provide for future extensions toward the development of an urban goods forecasting model system.

Because the purpose of this paper was to structure the methodology, specific classifications for firms and goods have been introduced. Emphasis, however, was on strategy, inasmuch as any number of consistent classification schemes may be used within the described framework.

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A FRAMEWORK FOR THE ANALYSIS OF DEMAND FOR URBAN GOODS MOVEMENTS

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The purpose of this paper is to establish principles and procedures for the analysis of demand for urban goods movements. A classification of freight movements is proposed based on specific underlying characteristics of these movements, and attention is focused on the urban component of goods movements. This focus is established and justified by considering the relative magnitude of the urban problem, its impacts on the quality of life, and likely trends of the future balance between urban and interurban goods movement. Similarities of and differences between passenger and freight transportation are pointed out as an aid to the development of analytical approaches to prediction of the demand for freight movements. Some basic definitions concerning urban goods movements are proposed. A case for research into urban freight demand, built in part on consideration of the best mix of short-run and long-run solution strategies to urban goods problems, is established. It is also based on an identification of the problems that have arisen in the passenger transportation system as the result of inadequate passenger demand analysis. Strategies are suggested by which such a demand analysis can be initiated. The objectives for freight demand analysis are identified, and an empirical approach to their achievement is proposed. This empirical approach must be based on the collection of data on freight movements. These data requirements center around both consignment movements and vehicle movements, and the basic variables on which data are needed are identified. The lack of such data from previous studies is pointed out, and some specific problems associated with the collection of the required data are examined.

•THE PROBLEMS associated with urban goods movements were given only slight attention until about 2 years ago. The increasing attention paid to this topic is evidenced by recent papers and conferences concerned with identifying problems of freight movements. For the most part there has been a concentration on specific problems (e.g., the New York City garment district) and strategies to alleviate these problems. Relatively little attention has been given to the need for long-term research to identify underlying demand and to develop comprehensive planning strategies for freight movements.

Despite the importance of goods movements at all levels of the economy, transportation planners have been preoccupied with passenger transportation, particularly at the urban level and to a lesser degree at the regional level. For example, in the area of air transportation, air terminals and airport access are designed primarily, if not exclusively, for passenger movements. Thus, although about 50 percent of all air freight is moved in the bellies of passenger aircraft, no special loading, unloading, storage, or handling facilities are provided for freight at the passenger terminal.

There are several reasons for this lack of attention to the freight component of transportation planning. As cited by Fresko, Shunk, and Spielberg (1), the transportation planner, concerned primarily with planning a highway network, made several simplifying assumptions to obviate the necessity of studying freight movements. Furthermore, public, and consequently governmental, pressures demanding rapid solutions to conspicuous passenger transportation problems reinforced this passenger bias.

The lack of attention to freight transportation planning is all the more serious if we consider the cost of freight on the national level. Hille (2) states that in 1969 "it has been estimated that the Nation's freight bill accounts for approximately 9 percent of the Gross National Product while total physical distribution costs may run as high as 15 percent." It should be noted that that 9 percent does not include movements of parcels and mail, natural gas, and water. Similarly, in 1967 freight transportation accounted for approximately 45 percent of national transportation expenditures (1). Again, water, natural gas, and mail are not included in this figure.

Even though freight transportation has been an important component of the national economy for many years, there are now increasing pressures to devote more planning and research resources to the problems of freight movement. One of the reasons for this is the public's increased awareness of hidden costs within the price of consumer commodities, such as the costs of transportation. For instance, transportation costs represent an average of 20 percent of the cost of most manufactured articles and as much as 50 percent of bulk commodities such as coal. Given the fact that the average American consumer requires 1 ton of food and 7 tons of fuel per year, transportation costs clearly constitute an important component of an individual's budget. Coupling this individual consumption with the increase in population provides a further reason for these new pressures. Another reason stems from both the increased use of trucks for moving goods and growing concerns for the quality of the environment. Trucks are frequently criticized as a major source of noise, air pollution, and road wear. This perspective suggests that alternative methods of freight collection and distribution or more efficient vehicle use be investigated.

Finally, it should be noted that freight transportation plays an even more important role in the economy of developing countries. The desire of these countries to take advantage of current planning techniques and technology, together with increasing participation by countries such as the United States in the attempt to satisfy these desires, necessitates the ability to plan better for this important part of the economy. The primary focus of most network improvements in developing countries is directed toward improving freight movements by increasing accessibility to natural resources, to markets, and to export facilities.

THE PROBLEM

To define the problems of freight movements, we should identify the geographical classification of these movements. There are four basic types of freight movement. One type is import movement, which comprises the shipment into an area of goods to be consumed within that area. (The term consumed includes both direct consumption and manufacturing processes.) A second type of movement is export movement, which represents the shipment out of an area of goods produced within the area. The third type of movement is transient movement and includes goods passing through an area directly and also goods undergoing temporary storage and warehousing for carrier interchange, break-bulk operations, and so forth. The last type is intraurban collection and distribution and local shipment movement in which the vehicle, though not necessarily the commodity, has both its origin and destination within the same area.

All four types of freight movement have an urban component. In contrast, intraurban movements do not have an interurban component. This fact suggests justification for concentrating analysis initially on urban freight movements. Intraurban goods movements constitute an increasingly large share of total goods movements, while total goods movements are increasing at the same time. For instance, between 1945 and 1965 New York tri-state freight traffic grew twice as fast as the population (3). One of the reasons for the growth in intraurban goods movements is the process of urbanization that continues to affect the United States. Total U.S. urban population increased from 89 million to more than 129 million between 1950 and 1969, and during the same period suburban population grew from 41 to 55 percent of that total (4). To further illustrate the effects of increasing urbanization on intraurban goods movements, the proportion of export activities is radically less in large urban areas than in small ones. Meyer (5) states that, although a large-scale farming enterprise may export 80 percent or more of its total production, that figure would be as low as 20 percent in a large urban area such as Chicago.

Associated with the residential movement to the suburbs has been a trend for industry and commerce to follow this location pattern. This trend is due to the increasing cost of center-city property and the economies of land-extensive industry, which together provide an impetus for a locational shift of existing industry and commerce. Another reason is the increased demand for commerce and industry to service the growing suburban population.

Most of the available land for industry and commerce is located outside the commercial districts within which for-hire cartage may be offered (6). This means that a growing proportion of industry is forced to operate and maintain its private fleet of collection and distribution vehicles, thus militating against consolidation of urban goods movements and also adding to congestion problems in the urban area. A corollary to the rising urban population and growing industry and commerce is a trend toward greater self-sufficiency of large metropolitan areas. The increase in self-sufficiency leads to a greater proportion of urban goods movements and a consequent decrease in the proportion of export-import movements (5).

It is evident from this discussion that urban goods movements constitute the largest component of total freight movement. Furthermore, it is also the fastest growing component. Also, these freight movements occur in those areas where, at the same time, pressures of automobile congestion and traffic- and industry-generated pollution are greatest. These facts provide at least a partial justification for concentrating on the problems of urban goods movements.

There are also a number of operational and technological characteristics that account for the special role goods movement plays in the urban context. For example, almost identical technology is used for interurban and intraurban truck movements, even though the requirements for a line-haul movement are quite different from those for a collection and distribution activity. However, the vehicles are mainly designed for intercity movement and are often inappropriately equipped for the intraurban movement. Also, in urban areas, freight movements must be scheduled according to and are constrained by the working and operating hours of shippers and receivers, which forces the collection and distribution movements to take place during periods of greatest congestion on the urban street system. In contrast, the intercity transportation network is less subject to both congestion and peaking; furthermore, the intercity truck driver has far greater flexibility in arranging his driving schedule. This flexibility allows him to avoid urban congestion on the intercity movements by shifting his schedule appropriately.

From an economic viewpoint, there is a substantial cost difference between urban and interurban goods movements. This difference is due on the one hand to urban congestion and problems of distribution and collection of freight in urban areas and on the other hand to increased speed and efficiency of intercity freight movements. The trends of these two underlying factors serve primarily to increase this discrepancy still further. To illustrate the difference between the costs of intercity trips and solely intracity trips, one can examine the 1965 revenue for truck movements in the tri-state region (7). The revenue per ton-mile of export-import truck movements was 7.4 cents, whereas 68.2 cents was the revenue per ton-mile of intraregional truck movements. A similar difference exists for waterborne and rail movements. In total, import-export freight movements for the tri-state region in 1965 (excluding foreign freight) grossed revenue of $1,946 million, whereas intraregional movements grossed $2,269 million of which $2,208 million was by truck alone. From these figures, it becomes obvious that improvements in intraurban freight movements will have a much greater impact on the economy than would improvements in intercity movements.

COMPARISON OF PASSENGER AND FREIGHT MOVEMENTS

One approach to analysis of freight movements is to examine experience gained in dealing with the analogous problem of passenger movements. Freight movements can be viewed as the transportation of consignments between shippers and receivers. This transportation may take place by various modes and may involve modal changes.

Although the transportation planner is ultimately concerned with the movement of vehicles, such movements can only be arrived at through analysis of the demands for transportation of consignments. This is so because there is not a one-to-one correspondence between movements of consignments and movements of vehicles.

Before freight movements can be compared with passenger transportation, a distinction must be made between private automobile and public transportation. In the case of the private automobile, the occupant can generally be identified with the vehicle. Thus, person movements by private automobile can largely be equated with vehicle movements, which allows direct prediction of vehicle flows on the highway system. Clearly, person travel by private automobile shows very little similarity to freight movements. The characteristics of public transportation seem to be much more closely related to those of freight transportation. Transit movements comprise vehicle movements with one set of origins and destinations and person movements with a different set of origins and destinations. It then becomes necessary to determine the demand for person movements as a first step in predicting vehicle movements.

Freight movements like transit movements involve the phases of collection, line-haul, and distribution and possibly modal split. In both instances commodities or passengers can no longer be identified with the specific vehicles, inasmuch as they may enter or leave the vehicle system at any point along the route. Obviously the vehicle movements should serve the movement requirements of commodities or passengers. Although a certain degree of independence between vehicle movements and commodity or passenger movements will necessarily exist, particularly in freight transportation, this independence is undesirably excessive. Therefore, a major planning objective should be to optimize vehicle movements to best serve commodity or passenger movements within the constraints of vehicle operation.

It is obviously dangerous to extend parallels and analogies too far: This could lead to ignoring some major problem. A clear difference between public transit and freight transportation lies in the ability of passengers to respond to system failures and the inability of commodities to do so. Therefore, problems arising from system failure require a different treatment in freight analysis from that in public transit analysis. another dissimilarity is that the problems of warehousing and break-bulk operations find no parallel in transit movements. These exclusive freight problems are crucial in the context of intraurban freight movements and therefore require special attention. A further contrast lies in the current state of the freight vehicle system in relation to the optimization discussed earlier. Partial optimization already exists in public transit systems in which duplication of routes has largely been eliminated. However, because there are numerous independent freight carriers, extensive duplication in routing and scheduling occurs, particularly in large metropolitan areas.

SOME DEFINITIONS

In the absence of generally accepted definitions of freight movement terminology, the following are presented as a basis for discussion. Although the focus of this paper has already been established as urban goods movements, the term has thus far not been explicitly defined. To establish the definition of the term, we can look at each of the three words separately. We can define the word urban, as discussed here, as equivalent to intraurban, or it can refer to the urban component of all goods movements. Urban is defined as relating to the latter; however, no attempt is made to determine the geographical boundaries of urban areas.

The second word in the term, goods, also presents some definitional problems. In this context, a good may broadly be defined as any nonperson item that may require transportation. Such a definition would, however, include all retail purchases transported in private automobiles and transit vehicles, as well as equipment carried by service personnel. Furthermore, it would also comprise such commodities as gas, electricity, oil, and water. The definition proposed here is more restrictive inasmuch as movements of retail purchases accompanying people are already defined as person movements. To include these in the definition of goods would lead to double-counting of certain movements. Also, in the case of equipment movements accompanying service personnel, because these personnel may sometimes use private vehicles, they may be included in person movements. Furthermore, the equipment being moved is distinct from other goods in that it is not being shipped and received, but constitutes a part of a service operation. Another reason to restrict the definition is that movements by pipeline and transmission line do not require the type of vehicles of major concern to the transportation planner.

A good is defined here as any nonperson item that may require transportation and that is carried in a strictly nonpassenger vehicle or is carried in a passenger vehicle but is not directly accompanying a passenger. For the purposes of this paper freight and commodity are synonymous with good.

Service equipment is specifically excluded from this definition, inasmuch as the concern of this paper is with goods that are shipped and received. This exclusion is proposed only for the purpose of this paper and should not be taken as a general recommendation for the exclusion of service movements from future studies of freight transportation.

Finally, movements are defined as transportation of goods by various modes such as truck, railroad, airplane, boat, private automobile, bus, subway, pipeline, or transmission line. Again, in the context of this paper this definition includes too many vehicles for movement. Although all of these vehicles may operate in the urban area, the ones that are of concern to the transportation planner are those that may, and typically do, conflict with person movements in urban areas. Furthermore, movement of goods by private automobile has already been excluded. Thus, movements are defined as transportation of goods by truck, railroad, bus, or subway. The exclusion of airplanes and boats is not to be interpreted as the exclusion of access to airports and ports, which would be carried out by surface modes.

In addition to the definition of urban goods movements, it seems appropriate to clarify the meaning of the terms consignment, shipper, receiver, and carrier.

A consignment is a good or a group of goods with a single origin and a single destination. A shipper may be identified as the origin end of a goods movement and the receiver as the destination end. Because distinctions such as home-based and non-home-based, which are defined for person travel, do not exist for goods movements, origin end and production end are synonymous as are destination end and attraction end. Finally, the word carrier is defined as any vehicular carrier of goods including privately owned vehicles and common carriers.

THE CASE FOR RESEARCH ON DEMAND FOR URBAN GOODS MOVEMENTS

In the late 1940s and early 1950s, the urban passenger transportation system in the United States was faced with a series of crises centered around rapidly increasing urban congestion. Initially these crises were attacked by proposing immediate remedial action. Such actions were typically localized, were generally short-lived in effectiveness, and comprised primarily small-scale changes and improvements in road facilities. Such short-term improvement strategies were soon recognized as inadequate. Consequently, federal legislation was passed that required comprehensive urban transportation planning studies and that provided federal aid for major long-term improvements. Even so, the urban transportation planning procedures that were developed in response to this requirement were inadequate for, if not incapable of, explaining the underlying causes leading to the demand for passenger transportation (8, 9).

The lack of causality in these planning procedures has led to numerous shortcomings and problems, one of which was the highway bias prevalent throughout the 1960s. In fact, it is only in the last few years that transportation planners have recognized that highway-only solutions are totally inadequate to solve urban passenger transportation problems. There is now, therefore, increasing pressure to develop urban transportation planning procedures that provide insight into the underlying causality.

By now it may have become fairly obvious that a parallel can be drawn between the present urban freight situation and the urban passenger transportation situation of the 1940s and 1950s. Urban freight transportation is facing crises for which immediate short-run strategies have been proposed. In some cases, such as in the New York City garment district, these crises are so severe that they threaten the livelihood of an entire industry. Clearly, in such cases there is a need for immediate and short-term strategies designed to ameliorate the situation.

There is, however, a serious danger in concentrating exclusively on formulating and executing short-run strategies, as was the case when the country initially faced major crises in urban passenger transportation. This approach almost inevitably leads to suboptimization because it ignores the rest of the freight system, the passenger transportation system, and consideration of the total urban system context. The consequences of such suboptimization may easily lead to a worsening of the situation that these short-run strategies were intended to improve.

These statements are not to be understood as totally condemning short-run strategies, for such strategies are frequently called for, particularly to meet crisis situations. The ideal approach would be to achieve a suitable balance between short-run and long-run strategies, by recognizing the implicit characteristics of each of these strategies. Appropriate short-run strategies should be reversible and relatively non-capital-intensive. Thus, they would incorporate the necessary flexibility to permit correction of suboptimization and possible future negative consequences. Examples of such strategies might include organizational changes in parts of the freight industry and the use of controls and restriction on highway facilities (11).

On the other hand, long-run strategies will probably require relatively high levels of capital investment, much of which might be public investment, and they are likely to be irreversible (10). As a result of these characteristics, long-run strategies need to be supported by comprehensive analysis aimed at, among other things, determining what benefits will accrue and to whom. "If existing knowledge is not adequate to perform such an analysis, then appropriate research . . . projects should be undertaken to gain that knowledge before an unwise decision and investment is made with scarce public resources" (10). Behrens (11) illustrates this point by quoting the example of the Calumet-Sag navigation project in Chicago, authorized in 1946. Had shortage of funds not delayed the execution of the second stage of this project, a major investment would have been made in navigational improvements that have since been shown to be unnecessary. The construction of a consolidated freight terminal by the Port Authority of New York and New Jersey, which has failed to find acceptance by the freight industry, is another example in which the failure to carry out comprehensive planning analysis has been a contribution to a possibly inappropriate investment of public funds.

Finally, it must be recognized that, unlike urban passenger transportation, freight transportation typically involves large numbers of private commercial operators. Yet the strategies discussed here are likely to be initiated by public agencies. Thus, ready acceptance of any strategies, short- or long-run, is not guaranteed, and legislation may be necessary to ensure their adoption. For example, consolidation of freight terminals or of local collection and distribution carriers is unlikely to be adopted by the industry, unless it is clear that there are commercial gains to be obtained from consolidation. Justification for consolidation may well exist primarily in its beneficial effects on the total urban system, rather than in the profitability of individual carriers. Thus, legislation may be required to impose socially desirable changes on the carriers. Such legislation must be based, however, on adequate comprehensive analysis demonstrating its desirability from an overall systems viewpoint. This analysis is the same as that required for long-run planning of freight transportation.

AN APPROACH TO DEMAND ANALYSIS

Basic Framework

The broad objectives of demand analysis of freight movements are to provide an ability to forecast probable future freight movements and to provide an evaluative mechanism of alternative strategies for dealing with freight problems. More specifically, a number of capabilities are needed to achieve these broad objectives. First, a capability is needed to determine the interactions between land use development or changes and the movement of commodities and to determine the concomitant vehicle movements on the transportation system. Second, relationships need to be established between urban growth and freight movements. Third, interactions among location, design, and operational characteristics of terminals and freight movements and also between carrier organization and freight movements need to be understood. Also, the relationship between commodity movements and the characteristics of the shipping and receiving establishments should be established. These interactions, which may involve legal and institutional matters, are important for both forecasting and evaluation and should also be predictable by the demand analysis. It is also necessary to be able to translate consignment movements into vehicle movements, inasmuch as vehicle movements are of prime importance to the transportation planner, whereas basic demand is for consignment movements.

The proposed demand analysis strategies should be designed for application at different levels of areal detail. Aside from forecasting and evaluating freight planning strategies at an urban or regional level, it should be possible to analyze the effects of strategies at a very localized level. For example, in the case of the New York City garment district, the major concern is to reduce the congestion and conflict problems in a relatively small area. However, strategies that solve these localized problems may have impacts on freight movements throughout the metropolitan area. Hence, there is a need to be able to carry out analysis over a wide range of levels of areal aggregation.

It is clear that this specification of demand analysis of freight movements is somewhat idealistic, particularly in view of the fact that, after 20 years of research and development, demand analysis of passenger transportation still falls short of its similar objectives. Perhaps one of the basic reasons that passenger demand analysis has not achieved its objectives is that these objectives were not clearly specified initially and much attention has had to be paid to providing rapid solutions to urgent problems. It is a major thesis of this paper that a similar approach not be adopted for developing capabilities in freight movement planning.

To develop the techniques for achieving the objectives of demand analysis requires that data requirements be identified that would underlie any such developments. Because these data requirements have largely not yet been established, their specification would constitute an essential first step toward determining the characteristics and structure of freight demand analysis techniques. It is probably convenient and not inappropriate to adopt and use the same terminology of travel demand components, i.e., trip generation, distribution, modal split, and network assignment, for freight movements as is used for person movements. The basic unit of analysis in freight movements is the consignment, which is comparable to the individual in person movements. The required data are therefore measures of the consignments and the environment within which the demand for movements of consignments occurs and also measures that relate consignment movements to vehicle movements on the transportation system. Because no empirical work has been done in the area of freight demand, the data requirements for such work, postulated in the remainder of this paper, must be taken as constituting a preliminary step on which initial empirical studies may be based (12).

Generation and Distribution

When the generation and distribution of consignment movements are considered, a number of parameters describing a consignment can be identified as necessary inputs to any analytic models. Clearly the demand for movement of consignments is related to the type of commodity being consigned. In addition, the physical attributes of a specific commodity consignment must also be determined. The great variety of parameters required to describe a consignment relates to the diversity in consignment characteristics, in contrast to the relative homogeneity of individuals in passenger transportation.

A classification system for commodity types is required such that the demand characteristics within any one type are relatively homogeneous. A number of classifications have already been proposed or are in use (13) that are not based on this requirement and may not, therefore, be appropriate for demand analysis at the urban level. For instance, it may be pertinent in urban demand analysis to consider as separate commodity types fuels for heating, fuels for power generation purposes, and crude fuel products such as unrefined petroleum. Wood (13) uses two classification systems for commodities: one defines these commodities as either "petroleum or coal products" or "coal" and the second defines them either as "fuel" or within a general category of "all other products." Although these classifications were appropriate for the descriptions in that paper (13), they are probably not adequate for demand analysis.

As indicated, data are needed on a number of different freight attributes. If the commodity type classification does not already define it, the physical state of the commodity, i.e., solid, liquid, or gaseous, is a necessary parameter. Other required parameters include the weight, volume, shape, value, shipping and insurance costs, origin and destination, time and date of dispatch, and nature (e.g., durable or frangible, perishable or nonperishable, etc.) (12). These characteristics describe a consignment.

Further, it might be expected that some of the characteristics would be partial determinants of the demand for movements of consignments (e.g., weight, volume, origin and destination, etc.), whereas others would be necessary inputs to models of modal choice and vehicle loading. (A vehicle loading model corresponds to an automobile occupancy model, in that it relates consignment movements to vehicle movements.)

The consignment characteristics and commodity type classification, which partially determine demand, refer to the quantity of demand and the likely number of consignment movements, but do not address the problem of determining the reasons for the existence of demand. To complete the picture of generation and distribution of consignment movements requires information on the characteristics of the shippers and receivers. In the same way that consignment characteristics are analogous to person characteristics in passenger travel, so are the shipper and receiver characteristics analogous to land use characteristics in the passenger trip generation phase. In the case of freight movements, shipper and receiver characteristics include land use classification, intensity of use (14), and parameters describing capabilities for, and restrictions on, freight handling. It is evident that the land use classification commonly used in passenger travel forecasting is inadequate for freight movement analysis because of the great diversity of freight movements generated within some of these standard land use categories. The freight land use classification should be based on homogeneity, in each category, of freight-generating activities and generation of freight vehicle movements. For example, the standard classification of industrial land uses into light and heavy industry clearly does not achieve the homogeneity required for freight demand analysis. The specific freight land use categories cannot, however, be determined a priori, but must be the subject of an empirical study.

Intensity of use, by a specific shipper or receiver, can be described by variables such as floor area, total employment, numbers in different employment categories (e.g., professional and managerial, manufacturing, etc.), and measures of input and output. The problems relating to relevant measures of input and output warrant some elaboration. For industrial and manufacturing categories, input and output can be measured as the physical weight or volume of incoming and outgoing products of the process and the incoming products required for the management and operation of the industrial or manufacturing concern. Based on the degree of detail of the land use classification, these two elements of processed input-output and input for management and operation may need to be kept separate for analysis or may be combinable into a single measure. For commercial land uses, the appropriate input-output measures might be the total volume or weight of incoming products and the total sales volume; similar distinctions can be made for other types of land uses.

The freight handling capabilities and restrictions can also be described by a number of parameters. These might include the number of loading docks available for each of shipping and receiving; the number of employees on the loading docks; the amount of storage available for incoming and outgoing shipments; institutional and legal constraints, such as restrictions on loading and unloading, parking regulations, and labor union rules; and capabilities for handling different forms of consignment packaging (e.g., containers, palletized consignments, and crates). This latter parameter would also generate the need for data on the handling requirements of consignments, thereby adding another parameter to the list proposed earlier in this section.

Finally, the shipper and receiver characteristics should include an accessibility or proximity measure relating to each potential mode of freight transportation. This measure would relate primarily to the inputs to the modal choice and vehicle loading models, rather than to the determination of the demand for consignment movements.

Modal Choice of Shipper

So far, no consideration has been given to the relationship between consignment movements and vehicle movements or to the shipper's modal choice included within this. Initially, a question has to be raised of how a mode is to be defined in the context of freight demand analysis. Clearly, a distinction has to be made not only among the traditional mode classifications of railroad, truck, and so on but also between different types of trucks. The delivery van can be considered as different from the tractor-trailer and should probably be treated as such. However, the case for further subdivisions within the truck group and the exact definition of potential submodes will necessarily have to await empirical analysis.

Once a definition of the appropriate modes has been determined, a number of parameters are needed to build models of modal choice and vehicle loading. The shipper's modal choice is likely to be determined by the relative times and costs of alternative modes; expectations of loss, damage, and pilferage; existence and availability of for-hire carriers or a private fleet of freight vehicles; characteristics of the consignments to be shipped; and location and accessibility of the origin and destinations of the consignments. Imposed on this choice may be a number of legal and institutional constraints, on which data will be required for freight demand forecasting.

At this point, the models and data requirements have been described that would provide estimates of the number of consignments to be moved between all origin and destination points in an urban area and the number of these consignments on each mode. It remains to be established how these numbers of consignment movements by mode can be translated into vehicle flows on the transportation network. This is the objective of the vehicle loading model mentioned previously in this paper. It does not appear that the need for a vehicle loading model has been explicitly recognized in the area of urban goods movements, nor does it have a strict analogy in the passenger transportation area. (Automobile occupancy is the closest analogy, but it is far simpler than vehicle loading in freight demand analysis.) Therefore, any statements on the components and structure of the model are somewhat speculative. The model should be capable of providing estimates of both the number of loaded and partially loaded vehicle movements and the number of empty vehicle movements. The translation of consignment movements into vehicle movements will probably be related to the availability, by capacity, of vehicles, the characteristics of the consignment, the proportion of vehicle capacity required by each consignment and the total volume of consignments from each shipper in a specified time period, ability to hold up shipments until a full vehicle load is achieved, and characteristics of the desired pickup and delivery pattern of the vehicle. (One vehicle may pick up small packages from many destinations, particularly a for-hire carrier, whereas others may serve one origin and many destinations.)

The model building procedure, described below, is shown schematically in Figure 1. The procedure for using these models to estimate urban freight demand is shown in Figure 2.

Other Issues

In comparison with the demand modeling package for urban passenger transportation, one phase, assigning vehicle flows to transportation networks, has been ignored in this paper. The assignment procedure has different problems and degrees of complexity for each of the freight modes considered. For example, in the case of rail travel, the assignment will likely be simple in terms of route taken but complex in terms of the way in which an individual freight car will be scheduled along a route (15). In contrast, intraurban truck movements comprise multiple collection and delivery operations and single origin-destination movements (including through traffic). With multiple operations, a large part of the vehicle route may be determined by the location of the collection and delivery points, which leaves little, if any, assignment problem. The most illustrative example of this is the mail delivery truck. The single origin-destination movements, on

Figure 1. Process of model generation for urban freight demand.

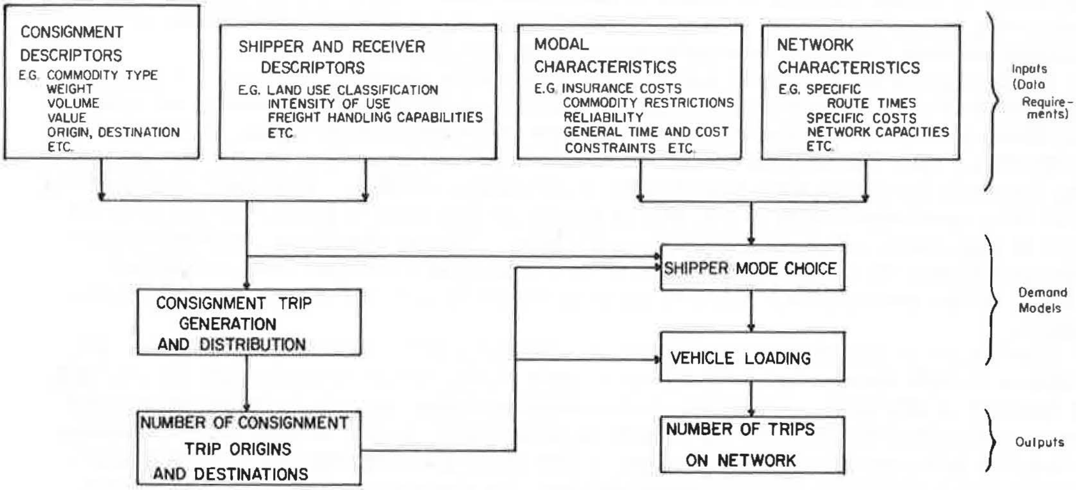
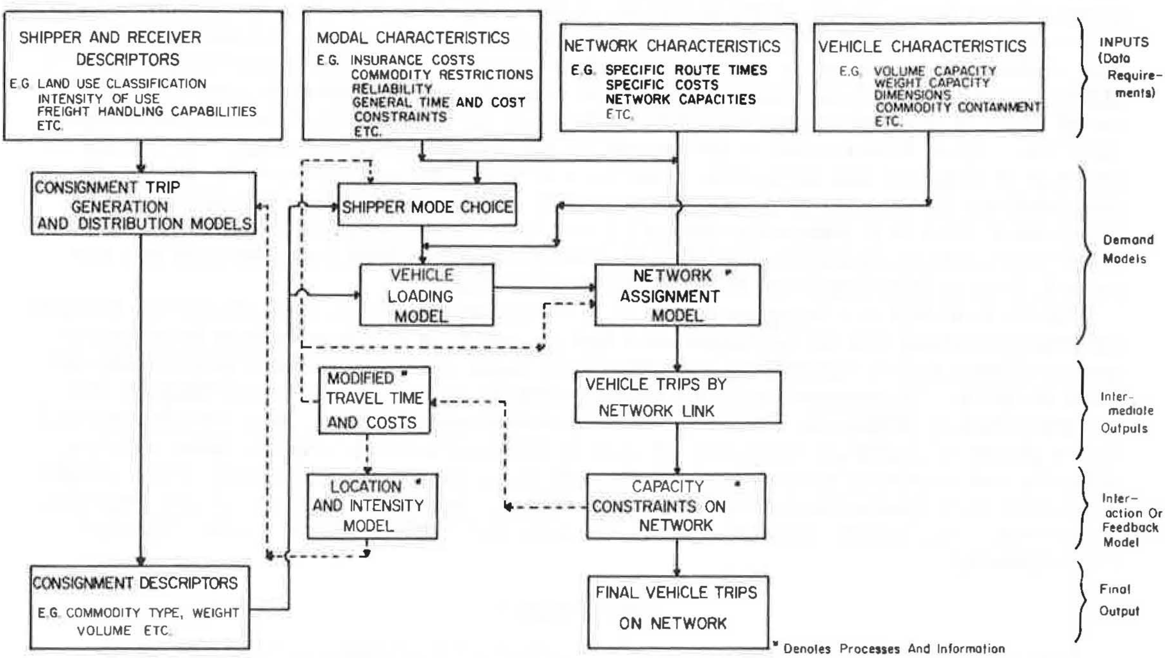


Figure 2. Procedure for urban freight demand estimation.



* Denotes Processes And Information Not Discussed In Detail In The Text.
---→ Denotes Feedback Links

the other hand, represent a relatively standard minimum time path assignment problem constrained by designated truck routes in the urban area. However, assignment is clearly not a major component of demand prediction, and a detailed discussion of this important problem therefore lies outside the scope of this paper.

In examining the underlying causality of urban freight demand, this paper has so far concentrated on the demand for commodity movements generated by existing (or given) urban development. As is the case in passenger transportation planning, the opposite relationships, i.e., the demand for urban development and growth generated by the existing demands for commodity movements, have been neglected. This omission does not reflect the importance of the issue, but is rather an indicator of the perceived state of the art in explaining and modeling this causal link. This is clearly an issue of considerable importance in freight demand analysis and warrants a major research effort. However, at the present time it is not clear to the authors how this research should be initiated.

A third issue in freight transportation, namely that of the location, operation, and function of freight terminals and their associated modal interface problems, has largely been ignored in this paper. Solutions to terminal problems should logically be derived from an analysis of the demand for freight movements by mode, origin, and destination. Because the primary objective of this paper lies in establishing the framework and determinants of demand for freight transportation, the discussion of terminal problems cannot be viewed as central to the thesis put forward here.

This paper has dealt at some length with a specification of the data requirements for initiating urban freight demand analysis. However, little attention has been given to the present availability of any of these data or to the methods by which currently unavailable data might be obtained. Among the possible sources of data are past urban transportation studies and the records of shippers and receivers. Typically, urban transportation studies have collected data on freight vehicle movements, but data are generally lacking on all aspects of consignment movements and even on the capacity utilization of freight vehicles. Thus, this course is inadequate for the demand analysis proposed. As for the records of shippers and receivers, there is a lack of standardization in the information recorded and the number of documents that contain the information. Furthermore, at the present time it is frequently difficult if not impossible to match the separate documents pertaining to a single consignment after that consignment has been sent and received, thus making inductive data synthesis infeasible.

The lack of data can be overcome in at least two ways. First, a standardized record-keeping procedure can be developed such that the records can be used both by shippers and receivers and by the analyst and still fulfill legal and institutional requirements for such records. The success of this approach clearly rests on cooperation between the freight industry (shippers, carriers, and receivers) and planners. The second approach is for planners to design and carry out surveys of freight movements by using existing shipping and receiving records and supplement these by direct observation, for example, of loading dock operations and terminal operations. Again, the success of this approach depends on cooperation from the freight industry, although to a lesser extent than the first approach.

CONCLUSIONS

It is clear that freight transportation, an important component of total domestic transportation, has been severely neglected in the past. However, problems of freight transportation are now reaching crisis dimensions that demand proposal of effective solutions. Because most of these crises arise in urban areas, the primary focus for research should be analysis of urban freight movements. The major obstacles to providing lasting solutions for these crises lie in the lack of understanding of the underlying demand for freight transportation in urban areas and in the lack of comprehensive and appropriate data on freight movements. Unless these obstacles are overcome, there is a danger that all the solutions proposed will be short-run and that these short-run solutions will compound the problems in the long run.

There is a strong temptation to adopt the analytical approaches that have been developed for urban passenger transportation as a means for providing the framework for analysis of demand for urban goods movements. Although many lessons can be learned from urban passenger transportation demand modeling, it is obviously inappropriate to draw these parallels too rigidly. However, an appropriate modeling approach to freight transportation can follow an analogy to the passenger transportation model sequence, although the specifics of each of the models will be different. The basic unit of analysis in freight transportation is the consignment, and vehicle movements should be derived from the transportation of such consignments.

To initiate the empirical development of demand models for freight movements requires detailed data on consignments, shippers, receivers, and links between consignment movements and carriers. It does not appear that such data are currently available, and therefore strategies are needed to obtain this information. Initially, the most feasible approach appears to be to carry out surveys via observations of actual consignment movements and to supplement these with available transportation records.

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ENVIRONMENTAL IMPACT OF GOODS MOVEMENT ACTIVITY IN NEW YORK CITY

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The amount of freight handled in the New York City metropolitan region is roughly 570 million tons per year. For the most part, this movement is inefficient: Trucks are too lightly loaded, travel too many miles when compared to their delivery schedules, run at low speeds, and operate during hours of the highest vehicular congestion. Furthermore, the rail and water networks have not been used to their fullest capacity. Many goods that now travel by truck could be shipped just as easily by rail or water. The products of this inefficiency are traffic congestion, increased energy consumption, air and noise pollution, broken and worn-out highway pavements, and high commodity cost. The 1970 Federal Clean Air Act mandates that certain environmental standards be met by 1975 in all cities in America. Air pollution caused by trucks in the New York City CBD is so great that trucks have been identified in New York as a major environmental villain. The New York City Department of Air Resources has embarked on an unprecedented effort to determine the true environmental impact of goods handling in New York City and to seek a solution that will facilitate goods movement and ensure maintenance of air quality standards. An investigation by the Department developed some candidate strategies for rationalization of goods movement combined with enhancement of environmental quality. The primary responsibility for implementation must fall on the goods movement industry and the public monitors and regulators of that industry.

•ACCORDING TO the conference on urban commodity flow (1, pp. 4-5), "Urban commodity flow can be viewed as the result of human activity that occurs within a defined space. To maintain that activity requires that materials be imported for consumption and processing and that manufactured goods be exported. In the process of importing and exporting commodities, an urban metabolism occurs. In the tri-state region in and around New York City, for example, it is estimated that each person annually accounts for 210 tons of fresh water, 7 tons of fuel, 4 tons of general freight, 1 ton of food, and 1 ton of disposable waste."

THE URBAN GOODS MOVEMENT PROBLEM

Water supply and sewage clearly dwarf all other needs [about 3.2 billion tons per year of fresh water for the tri-state region (2)] on a tonnage and bulk basis. The bulk of commodities carried are construction materials, fuel, and food. Conventional freight volume for the region is roughly 570 million tons per year (Table 1). This total includes goods carried into, out of, and within the region.

It is apparent from Table 1 that trucks are the major mover of freight out of the region, carrying 56 percent of the total volume. More importantly, trucks carry 77.4 percent of the freight volume within the region. The movement of goods in the region is, for the most part, characterized by inefficient operations. As a result, the 77.4 percent of the freight volume carried internally by the truck corresponds to about 97.4 percent of the cost of moving goods within the New York region (2). Excessive vehicle-miles traveled, low productivity, low operating speeds, and short work schedules that coincide with the city's hours of worst traffic congestion are all conditions that characterize goods movement by truck. Trucks travel up to five times the actual pickup and delivery distances in their normal operations. On the average, trucks operating in New York City are loaded to less than 10 percent capacity. Average truck speeds in the city's CBDs are a mere 4 mph. In addition, most trucking occurs between 8:00 a.m. and 2:00 p.m. (3).

Cargo is carried on only about one-half (54 percent) of the trips made by an urban truck. Tools or equipment needed to perform services are carried on 23 percent of the trips, and the vehicle is empty on the remaining 23 percent (4).

Furthermore, the rail and water networks have not been used to their fullest capacity. Many goods that were previously shipped by rail and water now travel by truck. Rate structures have been set up so that it is often cheaper to use a truck where good rail or water connections exist. The Interstate Highway System has speeded up truck travel and further increased dependence on the truck.

The differences between intercity and intracity goods movements must be further emphasized. Whereas goods are transported between cities by truck, rail, air, water, and pipeline in large shipments, goods are transported within the urban area primarily by trucks in smaller shipments. Intercity freight operations are becoming more efficient (e.g., piggyback and container operations, some consolidation efforts, fuel for redistribution to Long Island received at the Northville Docks near Riverhead instead of being sent through the Port of New York), although they can still stand improvement. Local freight traffic operations, however, either are at a standstill or are becoming less efficient. Thousands of operators are involved, often duplicating services. Seventy percent of all trucks are single-vehicle operations, and less than 10 percent are in fleets of more than 20 trucks (4). When so many operators are involved, it is difficult to regulate them and to attempt to make their movements more efficient. These intracity movements appear to be the crux of the problem. The consequences of this inefficient goods movement operation are discussed below.

HIGH COMMODITY COST

In 1971 the nation's estimated freight bill was $101.8 billion, 9.7 percent of the gross national product. The nation's freight bill has been constantly increasing from year to year but has remained approximately 9 to 10 percent of the GNP. Fifty-four percent of the total cost of transportation goes for moving people and about 46 percent for moving goods. Seventy-nine percent of the $101.8 billion freight figure is attributable to transportation by truck (5). It is either difficult or impossible to further break down information on freight costs to show their direct impact on commodity costs or to attribute cost value to the socioeconomic effects of inefficient goods movement. However, some attempts have been made.

A detailed study of truck movement in a square mile of downtown Brooklyn was made by the Tri-State Transportation Commission in 1968 (6). The study showed that a large amount of waste exists in the present system. Approximately 4,000 trucks entered the area, more than 2,800 carried freight suitable for consolidation, and over 1,100 of these made more than one stop. These 1,100 trucks were analyzed, and the study states that, if consolidation were instituted, a potential savings of $3.3 million per year could be anticipated. It states further that, if other trucks with suitable freight were included, the savings achieved could reach as high as $8.1 million per year for the square mile area and $1 billion per year for the region.

An examination of pickup and delivery costs for New York City and the region shows the relationship between goods movement and the environment in which it occurs. Rough estimates indicate that costs for the middle Atlantic region are 19 percent higher than average, northern New Jersey 45 percent higher, and New York City 62 percent higher (7). The increasing effects of congestion, inadequate loading facilities, and so on are amplified closer to highly urbanized areas, which raises pickup and delivery costs and results in higher commodity costs.

A Canadian study estimated that the total cost of transportation in 1966 for all Canadian cities with a population of more than 100,000 was $530 per person per year. This was broken down into $280 for goods trucking and $250 for person transport (with no value on unpaid time). It further estimated savings per person per year by the year 2001 at $190 to $230 if the system of moving goods were improved by consolidation, new technology, improved facilities, street and traffic improvements, and so on (1).

Whereas the accuracy of these studies or the assumptions made by them may be questioned, they serve to show the magnitude of the costs and savings involved. Again, costs do not include socioeconomic costs but only the costs of service performed.

INCREASED CONGESTION AND WEAR OF STREETS

Trucking has a strong impact on the physical and flow conditions of public highways. Blockage of traffic in narrow streets can be caused by the presence of parked trucks. The truck parking problem is exacerbated if elevators are inaccessible or internal building capacity is insufficient to accommodate shipments. In such places as the garment center of New York City, where many trucks are parked at curbside for hours while more wait for curbside access, vehicle speeds can drop to only 3 or 4 mph. Loading of large trailers in narrow streets can restrict traffic movements entirely, as in the narrow streets of lower Manhattan where the entire width of a street may be blocked.

The fact that trucks and automobiles have to share the same streets causes several problems. The overall vehicle flow is impeded because of different driver eye heights and ranges of vision and the slower acceleration and lack of maneuverability of trucks. Consider the case, for instance, of a tractor trailer and a Volkswagen trying to negotiate the same narrow urban street and not to collide with or sidewipe each other.

The poor quality of highways in areas of heavy trucking and congestion on narrow roadways raised the estimated cost of congestion in New York City to about $1 million a day in 1951 (8). An independent analysis of the cost of congestion in the garment center, prepared by the New York Trucking Association, estimates the annual cost of traffic congestion in midtown Manhattan at $150 million (9). Shipments are slowed down, higher costs for labor are incurred, and the costs are shifted on until the consumer is forced to pay.

Heavy vehicles require highways that are more structurally sound than those used exclusively for light-duty vehicles such as cars. Increased costs are incurred because of the necessity of providing strong subbases and more structural steel for roadway slab reinforcement and columns for elevated highways. Trucking necessitates the provision of stronger foundations to resist sidesway and bending moments of highway signs, lampposts, traffic signals, and bridge abutments. In short, the design of all roadways for all kinds of vehicles results in considerable additional expense above the cost of providing special roads for trucks and light-duty roads for automobiles.

Because of the damage of city streets caused by heavy trucks, the New York City Transportation Administration is developing legislation that will limit the dimension and weight of vehicles within New York City. Also, the Greater London Council has announced that it intends to ban heavy trucks from central London because they are "an inherent impediment and danger." Obviously, a reduction in truck traffic in central cities offers the potential for benefits other than reduced air pollution.

Increased Energy Consumption

The excess vehicle-miles traveled by trucks result in increased and wasteful consumption of fuel. As central city congestion worsens, fuel consumption is increased. This trend is further heightened by the fact that trucks, rather than rail, carry an increasingly greater percentage of the freight moved in the nation. Much freight that had previously been moved by rail is now being moved by truck. The replacement of one train by 200 trucks causes greater energy consumption, for the rail mode is inherently less energy-consuming and less polluting per ton-mile than the truck.

A report prepared by the Oak Ridge National Laboratory (13) indicated that transportation accounts for about one-quarter of the energy consumption in the nation. The report presents the following information on the relative energy consumption by mode:

Mode	Btu/Ton-Mile
Pipeline	450
Waterway	540
Railroad	680
Truck	2,340
Airway	37,000

This table shows energy use for the intercity truck and not the urban truck. It should be higher for the urban truck because of urban congestion and because intracity shipments are lighter than intercity shipments.

Increased Noise and Air Pollution

Whereas it has been generally accepted that transportation sources are the main contributors of air pollution in the city, it has not been known that trucks are a major source of air pollution (Table 2). It is currently estimated that 70 percent of all air pollution in New York City originates from transportation sources. In fact, however, in midtown Manhattan, trucks contribute almost 50 percent of the vehicle-related pollutants, and, in downtown Manhattan, they contribute more than 65 percent (Table 3).

At this point, it is difficult to quantify the effects of trucks on ambient noise levels. However, some data indicate that, whereas average noise levels on the busier city streets range from 70 to 75 dBA, trucks cause peaks of 88 to 97 dBA. Their contribution to New York City's air (and noise) problem could be minimized by improving operating efficiency. The New York City Department of Air Resources (DAR) estimates that, by cutting excess vehicle-miles traveled in half, by increasing the average load factor to 30 percent, and by increasing the average vehicle speed to 15 mph, the truck-caused pollution in the CBDs could theoretically be cut by 90 percent.

Involvement of the N.Y.C. DAR in the problem of urban goods movement has been caused by this last consequence of inefficient goods movement—increased air pollution.

FEDERAL MANDATE

The Clean Air Amendments of 1970 mandate that all areas of this nation meet primary and secondary air quality standards that are considered safe for public health and welfare by July 1, 1975. (This was later extended to July 1, 1977, for certain areas of the country, including New York City.) On April 30, 1971, the administrator of the Environmental Protection Agency published national air quality standards as required by the amendments. These include standards for six pollutants: sulfur oxides, particulates, carbon monoxide, nonmethane hydrocarbons, oxides of nitrogen, and oxidants. These standards are given in Table 4 (11).

Although according to the federal mandate the indicated standards may be exceeded only once per year, those standards most associated with motor vehicles, carbon monoxide and hydrocarbons, are exceeded regularly in New York City at levels from 5 to 50 times federal standards. It is estimated that the City can only meet these standards if passenger vehicles, including taxicabs, comply with federal standards; if heavy-duty truck emissions are dramatically lowered; and if much vehicle traffic is simply restricted. Data given in Tables 2 and 3 show the relative effect of trucks in Manhattan and its CBDs. Unless major improvements are made in trucking operations and in controlling emissions from trucks by 1977, very little change in mass emission will occur, and the truck's percentage contribution will increase dramatically.

The federal mandate also stipulates that the states are required to submit to the Environmental Protection Agency implementation plans describing how they will meet and maintain the standards. The Implementation Plan for the New York City Metropolitan Area was submitted in January 1972. EPA chose to accept the New York State plan with respect to those pollutants primarily associated with stationary sources (sulfur oxides and particulates) but rejected that part of the plan dealing with pollutants most commonly associated with mobile sources.

The New York City DAR and the New York State Department of Environmental Conservation are preparing a detailed plan for mobile source pollution, which is to be

Table 1. Use of conventional freight modes in tri-state region, 1965.

	Mode					
Tons Carried	Water	Truck	Rail	Oil Pipeline	Air	Tons (millions)
Into region	43.5	23.4	24.8	8.2	0.1	191.4
Out of region	18.2	56.3	13.2	11.9	0.4	79.5
Within region	21.2	77.4	1.3	0.1	—	298.1

Table 2. Motor vehicle emissions in Manhattan, 1970 (10).

	Hydrocarbons		Carbon Monoxide		Oxides of Nitrogen	
Mode	Tons	Percent	Tons	Percent	Tons	Percent
Automobile	26,868	58.9	189,312	55.3	10,445	45.7
Truck						
Gas-powered	9,867	21.6	85,789	25.0	1,218	5.3
Diesel	716	1.6	1,239	0.4	2,453	10.7
Bus						
Gas-powered	26	0.0	128	0.0	8	0.0
Diesel	1,153	2.5	2,197	0.6	4,231	18.5
Taxi						
F-M	3,562	7.8	32,789	9.6	2,625	11.5
NF-M	2,029	4.4	17,953	5.2	1,007	4.4
N-M	1,432	3.1	13,101	3.8	540	2.4
Total	45,653		342,508		22,841	

Note: F-M = fleet-owned medallioned type; NF-M = non-fleet-owned medallioned type; N-M = nonmedallioned type.

Table 3. Motor vehicle emissions in the downtown and midtown CBDs, 1970.

	Midtown CBD						Downtown CBD					
	HC		CO		NO_x		HC		CO		NO_x	
Mode	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent
Automobile	1,531	13.6	12,807	13.8	510	10.9	1,472	17.1	12,598	19.0	495	14.9
Truck												
Gas-powered	5,293	47.3	40,710	43.9	578	12.3	5,859	67.9	45,069	68.0	641	19.2
Diesel	328	0.0	591	0.6	1,106	23.6	364	4.2	655	1.0	1,227	36.8
Bus												
Gas-powered	—	—	—	—	—	—	—	—	—	—	—	—
Diesel	231	0.0	437	0.5	845	18.0	170	2.0	329	0.5	637	19.1
Taxi												
F-M	2,044	18.3	20,556	22.2	1,051	22.4	410	4.8	4,125	6.2	211	6.3
NF-M	1,449	12.9	14,285	15.4	509	10.9	290	3.4	2,857	4.3	102	3.1
N-M	317	0.0	3,247	3.5	85	1.8	62	0.8	638	1.0	17	0.5
Total	11,193		92,633		4,684		8,627		66,271		3,330	

Note: See note on Table 2.

Table 4. Air quality standards as required by the Clean Air Amendments of 1970.

		National Standard	
Pollutant	Averaging Time	Primary	Secondary
Particulate matter	Annual G.M.	75 $\mu g/m^3$	60 $\mu g/m^3$
	24-hour maximum[a]	260 $\mu g/m^3$	150 $\mu g/m^3$
Sulfur dioxide	Annual average	0.03 ppm	0.022 ppm
	24-hour maximum[a]	0.14 ppm	0.10 ppm
	3-hour maximum	—	0.50 ppm
Carbon monoxide	8-hour maximum[a]	9 ppm	9 ppm
	1-hour maximum[a]	35 ppm	35 ppm
Photochemical oxidants	1-hour maximum[a]	0.08 ppm	0.08 ppm
Hydrocarbons	6 to 9 a.m. maximum[a]	0.24 ppm	0.24 ppm
Nitrogen dioxide	Annual average	0.05 ppm	0.05 ppm

[a]May be exceeded only once a year.

submitted to EPA after this paper goes to press. The plan sets forth specific strategies to be followed to achieve federal air quality standards by 1977. Furthermore, long-range planning is discussed in light of the fact that these standards must be met by 1977; but, more importantly, they must be maintained. The responsibility for strategy implementation falls under the jurisdiction of city, regional, and state agencies.

GOODS MOVEMENT PROGRAM OF THE NEW YORK CITY DEPARTMENT OF AIR RESOURCES

Before the strategies are discussed, it would be appropriate to discuss in more detail the program of the New York City DAR with respect to goods movement. To achieve the following goals, DAR conducted a 3-month study in which people who are involved in goods movement were contacted:

1. To obtain information on completed, ongoing, and proposed programs that relate to goods movement;
2. To solicit ideas for improving goods movement and opinions of those contacted on which ideas would be most productive;
3. To ask those contacted which ideas they felt would be best tested by a demonstration project;
4. To obtain information on goods movement activities and patterns by truck, rail, and other modes;
5. To determine the impediments to efficient goods movement; and
6. To collect relevant reports, studies, and other documents to form the basis of a goods movement library.

The interviews involved people in government and private industry including study groups, educators, unions, shippers, and rail operators. The most salient findings of the interviews are summarized below.

Consolidation and Other Ideas for More Efficient Operation

Although consolidation is viewed by most goods movement analysts and truckers as one of the most acceptable means of improving the movement of goods, there are a number of operational complications. Unregulated carriers, particularly, appear to want to keep separate brand-name identity on truck fleets. Consequently, the idea of surrendering one's identity to a neutral consolidator is frowned on and will remain an institutional impediment to that concept.

Along with the surrender of a certain amount of identity, consolidation will undoubtedly interrupt traditional door-to-door service arrangements of many carriers. Most retailers, besides being opposed to the concept of nighttime work hours, view the removal of door-to-door service as bordering on self-destruction. Moreover, with the ever-increasing problem of hijacking and theft, they are totally disagreeable to having to depend on another handling point (i.e., consolidator), thus running the increased risk of pilferage.

Labor cost is a crucial input when night shipping and delivery schemes are considered. Above all, differentials would have to be paid that could very easily make night operations uneconomical whether consolidated or not. If the concept of consolidation and/or night delivery is to be viable, participants will have to be assured increased security in goods movement.

In addition to consolidation and night delivery the use of partial condemnation was considered as a possible way for aiding in the reduction of congestion. Older warehousing blocks, especially in the garment district, are ill-equipped to efficiently handle the truck traffic and tonnage that flows daily into the area. Probably the greatest obstacles to efficient loading and unloading of goods are narrow street widths and the absence of off-street loading docks.

Partial condemnation involves having the city condemn the street or below-street grade area of a building's first floor in order to construct internal loading dock facilities (in coordination with a refined elevator network). Many existing buildings are deep (approximately 180 ft) and often have above-average ceiling height at grade; so conversion is not a physical problem.

Truckers and Shippers

Numerous truckers and shippers were contacted, and DAR obtained information on their day-to-day operations and problems. Several problems were continually mentioned: inadequate enforcement of traffic regulations for automobiles, poor docking and unloading facilities, narrow streets, and the waste of time looking for parking.

Many large freight operations are already consolidated to some degree. For example, E. J. Korvettes has a consolidation terminal in Bayonne, New Jersey, for all New York area goods. The U.S. Postal Service and United Parcel Service (having the two largest truck fleets in the city) have had to consolidate for operational efficiency.

These large shippers see the small truck operator as the problem, not themselves. This may indeed be the case. It turns out that most trucks are operated by individual owners or in small fleets. As mentioned before, 70 percent of all trucks are single operations, and less than 10 percent are in fleets of more than 20 trucks. It appears, too, that it is these small truck operators that operate their trucks with only a small percentage of capacity. The major shipper must and does operate his truck at near capacity because of economic reasons. It has been pointed out, though, that when a truck operator uses only a small portion of vehicle capacity it is because that is all he can deliver in 8 hours in a congested city.

Rail and Water Operations

At first glance, the public transit system appears to be a reasonable alternative to intraurban goods movement by trucks, and night use for freight purposes (i.e., off-peak passenger hours) seems logical. On further investigation, however, there are numerous impediments to the potential use of subways for goods movement. First, there are no facilities for vertical movement of goods from the street to the platform. Additional platform space for storage and loading and station sidings for unloading do not exist. The headways between trains appear to be too small to permit the unloading and loading of freight cars (although this might be offset by containerization). Furthermore, although the N.Y.C. Transit Authority has hundreds of stations, comparatively few business houses are immediately adjacent to them. The cost of transferring freight from a motor truck to a subway car and again to a motor truck would probably be prohibitive.

Most if not all of the new rail activity in New York City has been going on at the Brooklyn waterfront. For example, whereas most major railroads are getting out of the business of car floating and lighterage (or are charging for these services), the New York Dock Railway has provided an overwater rail connection between New Jersey and the Brooklyn waterfront through its own car floats. Container ports are being developed at the Northeast Terminal and Redhook facilities. American President Lines has moved its cargo operation from New Jersey to Brooklyn.

Attention should also be directed to the state of the Long Island Railroad's freight operation, an operation that goes millions of dollars into the red each year. Because of Interstate Commerce Commission and Public Service Commission regulations, the LIRR has poor rate divisions with other railroads, and the ICC and PSC have made it possible for railroads to give discounts to shippers who instead of using rail, truck goods from New Jersey, thus reducing business for the LIRR.

Government

It appears that the actions of local, state, and federal government have not been directed toward improved goods movement. Many truckers feel that they are getting little cooperation from the city government in an atmosphere where congestion makes goods movement a difficult undertaking. In particular, they feel that the traffic and police departments have been rather lax in their ticketing of illegally parked automobiles while enforcement against the trucking industry has been overzealous.

The Interstate Commerce Commission, the Public Service Commission, and the Federal Maritime Administration are responsible for establishing trucking, rail, lighterage, and car float tariffs. Before any inroad into improving goods movement is made, a dialogue must be set up with these organizations.

The insight and comments of those individuals involved in the day-to-day problems of goods movement are valuable and have been used in the formulation of a set of strategies for the New York City Metropolitan Area Air Quality Implementation Plan for transportation-related sources (12).

Involvement of the N.Y.C. DAR with goods movement did not end with completion of the study. Because of the complexities of the urban goods movement problem (i.e., its economic and social effects and the effects on the environment, transportation, and urban form) and because a number of N.Y.C. agencies promulgate rules and regulations and make judgments affecting the movement of goods, DAR promoted the formation of an interagency goods movement technical committee. The committee was formed in September 1972 with representatives from four City agencies: the Transportation Administration, the Economic Development Administration, the Department of City Planning, and the Environmental Protection Administration. Its formation means that, through an interagency approach, New York City can start to develop solutions to its complex goods movement problem.

The committee is currently working on a grant proposal with the City College of New York for improving goods movement (in light of the creation of an automobile-free pedestrian zone) in downtown Brooklyn. It will shortly be preparing a policy statement on goods movement and will participate in the review of the Air Quality Implementation Plan.

THE AIR QUALITY IMPLEMENTATION PLAN

The strategies of the Air Quality Implementation Plan for significantly reducing the contribution of mobile sources to air pollution are broken up into five groupings:

1. Vehicle emission control strategies,
2. Traffic control strategies,
3. Public transit strategies,
4. Goods movement strategies, and
5. Long-range strategies.

With the exception of the public transit strategies, all of the other strategies directly affect trucks and trucking activities. Before these are discussed in detail, one point should be mentioned: The private automobile and taxi also contribute to the goods movement problem, in that they slow down traffic and cause parking interference. Strategies for reducing the vehicle-miles traveled by these vehicles, as suggested in the Air Quality Implementation Plan, must be implemented. Methods of achieving this include strict enforcement of traffic regulations, reducing parking availability for automobiles, and regulating vehicle mix. Those strategies most directly affecting trucking activities are discussed below.

Retrofit of Heavy-Duty Gasoline-Powered Vehicles

Regulation of emission levels from new vehicles of over 6,000 lb gross vehicle weight (gvw) has lagged behind efforts to control light-duty vehicle emissions. In 1968, exhaust standards were promulgated to take effect with 1970 model heavy-duty vehicles. Included are smoke standards for diesel engines and CO and HC standards for gasoline engines. In September 1972, the Environmental Protection Agency promulgated more stringent standards to take effect with the 1974 model year; NO_x emissions from heavy-duty gasoline engines are regulated for the first time. As with light-duty vehicles, these heavy-duty vehicle regulations are later and less stringent than those adopted by California, the only state currently allowed by law to enact emission standards for new motor vehicles or engines. Until the 1974 model year, the standards were so mild that manufacturers had to make only minor engine adjustments to obtain certification. The result of this laxity of emission rate limitations coupled with inefficient operating characteristics is that these vehicles are a major pollution source in midtown and downtown Manhattan and in the CBDs of the other boroughs. Retrofitting pre-1974 trucks with emission control devices should help reduce truck emissions greatly, not only because of the uncontrolled nature of truck emissions but also because of their great contribution to vehicle-miles of travel in the CBD.

Heavy-Duty Vehicle Emissions Inspection

Motor vehicles over 6,000 lb gvw have been subject to minimal emissions control standards since the 1970 model year. These standards and the somewhat stronger standards enacted for 1974 models will be inadequate to control commercial vehicle emissions in New York City. Engine deterioration results in severe increases in the emission rates of vehicles in use. Periodic emissions inspection identifies vehicles that need maintenance to minimize emission rates. Inspection standards would be set according to vehicle age and size and would recognize three additional categories.

1. 1970 and later model vehicles would be inspected to ensure compliance with federal standards applicable when new and for the "useful life" of the vehicle, defined as 5 years or 50,000 miles. Earlier model vehicles would have to meet reasonable emission standards based on model year.
2. Retrofitted vehicles would be inspected to determine presence of approved control devices and compliance with relevant emission standards.
3. Vehicles for which retrofit was not mandated would have to meet emission standards established as consistent with reasonable maintenance of vehicles in the size, engine type, and age class.

Because the high mileage accumulation typical of commercial vehicles causes an annual emissions contribution out of proportion to their number, emissions inspection will be required twice yearly.

Consolidation of Trucking Activities

As stated before, urban trucks are loaded far below capacity, and thousands of operators are involved, often duplicating services. When so many operators are involved it is difficult, if not impossible, to regulate them and thereby to make their movements more efficient. Varying degrees of consolidation could be attempted, e.g., pooled delivery system for just one commodity like bread; consolidation for small geographic areas like Co-Op City; consolidation for all deliveries for midtown Manhattan. Such action requires the construction of large freight terminals where goods can be consolidated for delivery by vehicles operating with near-capacity loads.

Improvements in Goods Movement Technology and Management Systems

Technological and management solutions will provide some of the answers to the goods movement problem. For example, in order for the concept of consolidation terminals to work, the terminals will have to be carefully located and designed by using modern material handling and management techniques. Technology will help in the design of small containers for use in night deliveries. Management techniques will aid in the development of computerized pickup and delivery schedules for areas of the city requiring random truck movements. New techniques will be needed, and those already existing, e.g., container-on-flatcar (piggyback) and electronic sorting of packages need to be promoted. The subway system has potential for moving goods. Whereas it appears that the use of subways for moving goods on a general citywide basis is not feasible, it may be possible to use them in certain cases (e.g., to move goods from one urban subcenter to another, from one industrial park to another). From a long-range planning point of view, the creation of satellite goods distribution centers, tied closely with the development of urban subcenters and industrial parks, is desirable.

After-Hours Delivery to Stores and Office Buildings

After-hours goods delivery would take delivery trucks off the streets during peak congestion hours. Stores and office buildings would be required to remain open late 1 or more nights a week. An alternative to this approach, which eliminates the need for personnel to be on hand to receive shipments, is the use of night cargo drop facilities (on the idea of night mail drop facilities). Some food chains have used night goods delivery for a number of years, but there appears to be no other extensive use of night deliveries.

Provision of Off-Street Loading Facilities

Many warehousing blocks and commercial buildings are ill-equipped to efficiently handle their incoming and outgoing truck traffic and tonnage, and so streets often become blocked by trucks parking on the street to load and unload. Furthermore, truck drivers spend excessive amounts of time searching for parking. The best example of this situation in New York City is the garment district in Manhattan (a study by the N.Y.C. Transportation Administration to formulate solutions to the goods movement problem in this area will soon be under way). Vacant lots or the ground floors of certain buildings can be used to provide off-street loading facilities. Using the ground floors of certain buildings would involve renting some vacant storefronts and then modifying them or, in the long range, condemning the street or below-street grade area of the building's first floor in order to construct such facilities. New buildings are required by zoning regulations to have off-street loading facilities. Off-street loading docks can also be provided by requiring that present off-street parking facilities for automobiles no longer be used for automobiles but as unloading areas for trucks. This pertains to street-level parking lots and to underground facilities with necessary modifications.

Use of Rail for Transporting Commodities

The increased use of alternate modes of transportation, as well as the improvement of truck operating efficiency, will reduce the vehicle-miles traveled by trucks. Replacing 200 trucks by one train, for example, would reduce congestion, air and noise pollution, and energy consumption and, with more favorable rate structures, would reduce the cost of commodities. New York City (and the nation) has seen the opposite trend: the replacement of one train by 200 trucks with its negative effects. Much freight that had been moving by rail previously is now moving by truck with the consequence that there are a number of good rail connections that exist in the New York area that are underused. A perfect example of this situation is the movement of freight from New Jersey to Long Island. Many goods end the rail part of their journey in yards in New Jersey and are then trucked through New York City out to Long Island. Several alternatives become apparent.

1. Goods could be car floated from New Jersey to the Brooklyn waterfront and then shipped by rail to Long Island;
2. Goods could be sent by rail from New Jersey to the Selkirk Yards near Albany and then south over the Hellgate Bridge to Long Island; and
3. By using smaller freight cars Penn Central's tubes from New Jersey could be used at night (off-peak passenger use).

However, because of technical or economic problems these alternatives are not pursued. The condition of rail service in this country grows continually poorer; railroads are finding themselves in the position of discontinuing services and routes, and they charge for services that were previously free (e.g., lighterage) in order to survive economically. These present trends are environmentally unsound and must be reversed.

Development of Waterfront Facilities

Just as the rail network has been underutilized for freight movement, so has our water system. A revival of waterfront operations, similar to what is being done at the Brooklyn waterfront (e.g., car floating, container ports, dock railway operations) is needed. In addition, the location of alternate ports on Long Island for the delivery of goods to that area must be investigated.

Development of Special Trucks for Urban Service

A new design of trucks can make it easier and quicker for goods to be delivered. (In addition, new designs could be electrically powered, thereby eliminating the vehicle emissions.) For example, United Parcel Service trucks are specially designed by them for ease in loading and unloading. Because many trucks are loaded to only an average of 10 percent capacity, it appears that many businesses should be using smaller trucks. Vehicle owners must be made to justify the size of their trucks at registration time. A variable registration fee schedule should be designed to encourage the use of smaller trucks.

Liaison With a Local University

Inefficient movement of goods and people is a large urban problem, yet it is poorly understood. Little work on the problem has been done by anybody, including educational institutions. By establishing a relationship with a university more can be learned about the problem, and perhaps other universities can be stimulated to pursue it. The U.S. Department of Transportation has established a university research program designed to increase the contributions of universities to the solution of national, state, and local transportation problems. It has designated a separate fund for giving grants to universities for research under this program. The City College of New York has made contact with the N.Y.C. Transportation Administration to determine what transportation projects the latter would like to see done. Suggestions for projects are being submitted to the City College through the Goods Movement Technical Committee. A permanent liaison for goods movement at the college could be established through this program. Goods movement studies are just one area for possible joint city-university study.

These other strategies were developed after the N.Y.C. DAR made estimates of air quality levels if, to meet federal standards, vehicle owners in time replaced their automobiles with newer, "cleaner" ones through trade-ins. Estimates showed that pollution levels in the CBDs would still exceed the 1977 standards. Furthermore, if standards are met in 1977, the continually increasing use of motor vehicles will cause them to be exceeded again in the future.

IMPACT OF STRATEGIES ON AIR QUALITY

In preparation of the Air Quality Implementation Plan, estimates were made of the effect the strategies would have on air quality.

The effect on air quality of retrofitting heavy-duty gasoline-powered vehicles will vary with location in the city. The impact will be greatest in CBDs where truck use is heaviest, in particular, downtown Manhattan, the Bronx, and Queens. In such areas, projected air quality improvements (16) by 1977, as compared to 1970, are CO, 25 percent; HC, 20 percent; and NO_x, 5 percent. Borough-wide projected improvements are as follows:

Borough	CO (percent)	HC (percent)	NO_x (percent)
Bronx	5	4	2
Brooklyn	7	5	3
Queens	8	6	3
Staten Island	15	12	5

If heavy-duty vehicle inspection is considered as a strategy distinct from mandatory retrofitting, citywide air quality improvements are estimated to be 1 to 2 percent for CO and HC, and CBD improvements are estimated at 5 percent for CO and somewhat less for HC. It should be noted that any retrofit program is dependent on periodic inspection and maintenance, inasmuch as controls will not generally compensate for engine malfunction.

Specific estimates of impact on air quality of the remaining strategies are difficult to quantify and, in general, require more study. However, a few points can be made. The effect of the consolidation of trucking activities should be approximately proportional to the number of trucks removed from the streets. Improvements in goods movement technology and management systems will affect air quality depending on the level of operating efficiencies achieved, the extent of the diversion of truck use to alternatives (rail and water), and so on. The effect of using rail and water for moving commodities will also depend on the extent of the diversion of activities from trucks. The impact of new truck design is equally difficult to estimate although an electric vehicle fleet could, for example, have dramatic impact in the garment district. No estimates of the impact of the provision of off-street loading facilities and the after-hours delivery of goods have yet been made; more study is essential.

It should be pointed out, in passing, that strategies for rationalizing the movement of goods not only will improve air quality but will result in time and cost reductions for shipper, carrier, consignee, and ultimately the consumer.

CONCLUSIONS AND SUMMARY

Although there have been some improvements in the intercity and international shipment of goods, there have been virtually no improvements in the intracity movement of goods. Excessive vehicle-miles traveled, low productivity, low operating speeds, and short work schedules that coincide with the city's hours of worst traffic congestion are all conditions that describe urban goods movement. Furthermore, rail and water movement, which is environmentally superior to trucking, has been allowed to deteriorate.

The increasing reliance on the truck for the movement of goods has produced a number of adverse effects: vehicular congestion, increased energy consumption, increased noise and air pollution, broken and worn-out pavements, and high commodity costs.

The problem of the urban truck and its impact on air quality can be resolved in two ways: by making changes in the vehicle itself and by making changes in the physical environment in which the truck operates (i.e., the methods of moving goods in an urban area). The Department of Air Resources has shown that without comprehensive measures of trucks and trucking activities and by reliance solely on the turnover of vehicles, federal air quality standards will not be met. In addition, because emission control standards are far more stringent for automobiles than for trucks, trucks will be contributing an even greater share of motor vehicle pollution in the future. In fact, without such controls, they will be the single greatest source of air pollution in the city's CBDs.

The strategies suggested for New York City have application in virtually every other urban area in the country. The rationalization of goods movement in a dense urban area like Manhattan can allow other cities with dense central cores to remain viable.

RECOMMENDATIONS

Strategies that will reduce the negative environmental impact of trucks operating in the urban environment have been outlined. However, further study is still required before those strategies can be successfully implemented. The following indicates the subject of study for each strategy:

1. Heavy-duty vehicle retrofit—completion of retrofit device evaluation is required by the Department of Air Resources along with full cost-benefit analysis.
2. Heavy-duty vehicle emissions inspection—a complete test procedure must be developed by the EPA and the N.Y.C. DAR. An emissions survey is needed to establish standards.
3. Consolidation of trucking activities—a preliminary study is required to determine the location best suited for demonstration. A plan for the metropolitan area is required, which should be integrated with the plan for New York City and the development plan for industrial parks.
4. Improvements in goods movement technology and management systems—a study is required to investigate the range of alternatives and evaluate their applicability within the metropolitan area.
5. After-hours delivery to stores and office buildings—the concept must be evaluated and those areas of the city that require nighttime delivery to reduce congestion should be determined.
6. Provision of off-street loading facilities—completion of the Garment Center Transportation Study is required. A further study to determine locations in the city where impact would be greatest would also be necessary.

7. Use of rail for transporting commodities—the metropolitan area should be analyzed in detail to develop a list of potential projects and to examine their feasibility.

8. Development of waterfront facilities—a detailed analysis to determine the feasibility of waterborne freight movement in the metropolitan area is required.

9. Development of special trucks for urban service—a study is required to develop vehicle specifications and market potential.

10. Liaison with a local university—general goods movement research and development are required.

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CANADIAN STUDIES OF URBAN GOODS MOVEMENT—A STATUS REPORT

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This paper briefly reviews several current Canadian research projects and then reports in a little more detail on the one with which the authors are most familiar. An interim report is given on the Transportation Development Agency project. This is a long-range, multiphased program, undertaken by the Canadian government, that is aimed at improving the movement of urban goods in Canadian cities. The first two phases of this work were completed in 1972. Phase 1 was essentially a research project in which candidate improvements to the present urban goods movement system were proposed and computer simulation models were developed to test these improvements. As a by-product of this work, a new urban goods classification system was developed in preliminary form. Phase 2 was an extensive field data collection project carried out in the city of Calgary. A third phase is under way. In this phase, the candidate improvements will be tested by using the phase 1 models and the input data generated from phase 2.

•A SUBCOMMITTEE of the Roads and Transportation Association of Canada deals exclusively with the topic of urban goods movements. On this subcommittee are represented all points of view—shippers, truckers, consolidaters, and government at the three levels. The committee has identified a number of potential improvements and established a subgroup to work on each.

One is the provision of consolidated shipping and receiving facilities to serve large buildings or blocks. Work on this is being headed by Carmichael of the Canadian Industrial Traffic League (1). A survey is being made of such facilities.

At the University of Toronto, Hauer has done some work on truck routes in cities. He has analyzed what has happened in this connection throughout Canada (2). He finds the situation to be chaotic and irrational.

The regulation of street space through parking restrictions and various other regulatory measures is being reviewed by employees of the City of Hamilton. They have sent out questionnaires to all larger cities in Canada and have analyzed existing regulations and enforcement. With the cooperation of the Ministry of Transportation and Communications in Ontario, they have done a detailed survey in the City of Hamilton. The results of these two thrusts are being combined at the present time with some analytical work.

At the University of Waterloo, Hutchinson and others have been doing work on generation or demand. They have surveyed approximately 250 industries in the metropolitan Toronto area and have performed regression analyses on the truck trips generated by these industries (3).

THE TRANSPORTATION DEVELOPMENT AGENCY PROJECT

This project is being carried out by N. D. Lea and Associates Ltd. for the Transportation Development Agency, which is a governmental agency dealing specifically with transportation research and development work. This multiphased research project on the subject of urban goods movement is in progress.

Phase 1: Preparatory Modeling

The first phase included identification of candidate improvements, writing computer programs to simulate the benefits that may be gained from operating on these improvements, and running these programs with some readily available data so as to assess what the data requirements are for a more in-depth evaluation.

The first step was to identify candidate improvements. Data shown in Figure 1 identify 13 candidate improvements in summary form. They are identified through some rational analysis, a review of the literature, and discussions with those working on the subject. The first improvement is in shipping and receiving facilities. Second is to improve the operation of these facilities. Third is to improve the location of terminals including consolidation so as to reduce the number of terminals. Each candidate in Figure 1 has been categorized by possible implementing actions: not applicable, possible, or promising. Discussions of each of these candidate improvements have been published (4, 5, 6). Each candidate improvement was investigated in depth to identify the types of changes that must be modeled in order to simulate the changes that might effect some improvement in urban goods movement. One conclusion was that it is important to model the shipping and receiving facilities, which we have called end-point facilities. The model of end-point facilities is the micromodel. The micromodel simulates operations at end points (i.e., geographical or physical points at which loading/unloading or transfer occurs).

The micromodel is a transaction or queuing model (dynamic and probabilistic) written in the GPSS simulation language. It simulates the pickup, delivery, and transfer operations. The inputs required for this model are

1. Type of end point,
2. Amount of legal and illegal parking available,
3. Number of docks,
4. Number of men working at the facility,
5. Size of the yard,
6. Walking distances, and
7. Types of commodities and vehicles that the model can call up to use for that particular facility at that time of day (whether peak or off-peak).

By means of varying input parameters, the model can be used to simulate any combination of building type, land use, area in the city, time of day, and type of facility. In particular, six types of end points are each simulated in a different way by the micromodel.

1. No facility (curbside operation),
2. Laneway without dock,
3. Laneway with dock,
4. Yard only,
5. Off-street dock, and
6. Yard and dock.

During a run of the micromodel for a particular end point, each of the following operations is specified sequentially: A vehicle arrives at the end point. Vehicle type, shipment weight, and the number of pieces are selected. The weight per piece is calculated. It is determined whether the facility, i.e., the dock, is available. If the dock is available, the truck enters; if the dock is full, the truck departs or enters a queue for the dock or looks for on-street parking. If the truck looks for on-street parking, it parks legally or illegally or departs. Once the truck is parked or in dock, the driver goes to the building, requests men or equipment (if required), goes to find agent, waits for agent, processes papers, waits for shipment preparation (if required), and returns to the truck. Loading or unloading or both take place. The truck departs. If the truck was parked illegally on street, third party (such as passenger car) delay time is calculated. These steps have been described for only one truck. However, in the model many trucks are each going through their operations simultaneously.

Two prime outputs are generated by the micromodel. The first is the total time spent by an average truck in performing the end-point operation. Subcomponents of the total, such as loading and unloading time and time to find a receiver and process papers, are also output. The second prime output is the total delay time experienced by passengers (in automobiles and public transit) in those cases where trucks are blocking traffic. Outputs from the micromodel serve as inputs to the macromodel.

Figure 2 shows a sample output from the micromodel. This is in narrative form for ease of interpretation.

The macromodel is a network flow model written in FORTRAN IV (equilibrium network model). It is similar in nature to the TRANSURB model previously used by N. D. Lea and Associates Ltd. in the Canadian urban transport efficiency study (7). Links represent the road system, and nodes represent zonal aggregates of end points. The macromodel calculates times and costs of trucking operations at three levels: over links, within zones, and at end points. Passenger delay time is also accumulated over links and at end points. The major steps in the macromodel are as follows:

1. Characteristics of links, nodes, vehicle types and costs, and O-D distribution tables by commodity are input (O-D distribution of goods is not modeled).
2. Each commodity O-D movement is assigned to one vehicle type.
3. Time and cost to move over each link are calculated for each vehicle type at the free speed.
4. The O-D demand is assigned over the network on the basis of either minimum time or minimum cost.
5. Congestion time and cost are calculated on each link.
6. Flows on congested links are reassigned by using a minimum path spanning tree technique. Only one such interaction is required.

Steps 1 through 6 calculate time and cost over links.

7. Free speed inside each zone is input.
8. Congested speed inside each zone is calculated based on congested speed-free speed ratios of zone incident links.
9. Total number of truck stops inside each zone is input.
10. Average trip distance between stops inside each zone is input.
11. Cost and time between stops are calculated based on the distance, speed, number of stops, and vehicle cost curves.

Steps 7 through 11 calculate time and cost between end points inside zones.

12. The percentage of each end-point type, by zone, is input.
13. Truck arrival rates are input as a function of end-point type and zone.
14. Total number of end points inside each zone is calculated from steps 9, 12, and 13.
15. Number of end points of each type is calculated for each zone.
16. Time and cost at end points are calculated from truck arrival rates, by using output curves from the micromodels, by end-point type and by zone.
17. Zonal (end-point) times and costs are aggregated.

Steps 12 through 17 calculate time and cost at end points.

The special features of the macromodel are that it deals with as many as 100 commodity types and as many as 10 vehicle types. It calculates for each commodity and vehicle type the total time and cost in the system, and it separates the congestion time and the normal time.

Figure 3 shows a sample summary output from the macromodel. In this summary truck results are grouped together, but they may be disaggregated by the 10 types if desired. The summary shows the quantities moved, the costs, and the times. In addition to these costs and times for normal network transport, the summary shows the costs and times for operation of end-point facilities and for vehicles at the end-point facilities. Then, on a zonal basis, intrazonal movements are also calculated so that the macromodel summary adds up the network costs, end-point costs, and zonal costs.

Figure 1. Means of achieving improvements in urban goods movement systems.

CANDIDATE IMPROVEMENTS	POSSIBLE GOVERNMENT ACTIONS										POSSIBLE INDUSTRY ACTIONS			
	BLD	Regulate					Encourage				Industry Cooperation			USER
		CODE	ZONE	CONL	LIC	TAF	TAX	LEG	RES	DEMO	R.D	STD	TAR	
1. Improve Shipping and Receiving Facilities			Possible	Possible			Promising	Possible	Possible	Possible	Possible	Possible	Possible	Possible
2. Improve Shipping and Receiving Facility Operation								Promising			Possible	Possible	Promising	Promising
3. Improve Terminal Location (Excluding Consolidation			Possible					Possible	Promising	Possible	Possible			
4. Improve Terminal Facilities									Possible		Possible			
5. Improve Terminal Facility Operation									Possible		Possible			
6. Consolidate Pickup and Delivery	Possible			Possible	Possible			Possible	Possible	Possible	Possible		Possible	Promising
7. Improve Pickup and Delivery Operations (W/O Consoidation)								Possible	Possible	Possible	Promising			
8. Improve Truck Design							Possible	Possible	Possible		Promising	Possible		Possible
9. Avoid Road Congestion - Operate Off-Peak				Possible		Possible				Possible	Possible		Possible	Possible
10. Other Measures of Reducing Road Congestion	Promising													
11. Rearrange Land Use - Alter Demand	Possible		Promising			Possible	Promising	Possible	Possible	Possible			Possible	
12. Improve Packaging						Possible		Possible	Possible	Possible	Possible	Possible	Promising	Possible
13. New Transport Modes	Possible								Promising	Promising	Possible			

☐ Not Applicable   ▒ Possible   ■ Promising

Figure 2. Sample micromodel output.

```
Micro Model base run simulation YARD AND DOCK PEAK

      Fields that are blank do not apply to this end point type

                          *** INPUTS ***

   Simulation length -  120 minutes.
   Arrival rate -    8.6 plus or minus   5.0 minutes.
   Number of docks -  3
   Number of men in addition to driver -  4
   Legal parking length -       feet.
   Yard length -  150 feet.
   Illegal parking length -       feet.
   Average walking distance from yard -    75 feet.
   Average walking distance from illegal parking area -   50 feet
   Average walking distance from legal parking area -  100 feet.

                          ***  RESULTS  ***

   End Point Summary:
        There were  13 trucks that arrived.
         13 trucks stopped to load or unload.
          9 trucks completed operations with an average total ti
            trucks parked on the street or yard.
               .0% parked illegally.
         12 trucks entered the facility.

   Common activities:
        The average time looking for an agent was   4.18 minutes
        The average time waiting for a signature was    1.40 minu
        Of the   6 pickups made the average loading time was   6
        The average pickup was 1232 lbs.
        Of the   5 deliveries made the average unloading time wa
        The average delivery was 1356 lbs.

   Dock activity:
        The average total time spent in the dock was  22.06 minu
        The average waiting time in the queue for the dock was
        The maximum length of the queue was   1
        The average time to maneuver was   1.50 minutes.
        An average of   2.96 minutes was spent waiting for men a

   Non-dock activities:
        The average time spent walking was    .00 minutes.
        Illegal parking caused     .0 hours of passenger delay.
```

Phase 2: Data Collection

One of the objectives of phase 1 was to identify the data requirements. This was done so that in phase 2 fairly intensive data could be gathered in one particular city with some assurance that the data would be relevant and useful. Thus, during summer 1972, field surveys were conducted in the City of Calgary. Five types of surveys were conducted.

Screen-Line Counts—Screen-line counts gave a measure of traffic flow by the vehicle type. Some results are given in preliminary form in Table 1. Totals do not equal 100 percent because categories with less than 0.1 percent were excluded. A high percentage of pickup truck trips is seen in Calgary because many of the small private operators use their trucks as recreation vehicles.

Cordon Counts—Cordon counts were performed in selected regions to obtain typical zone generation data by commodity category.

Truck Rider Surveys—Truck rider surveys are not normally undertaken because of the difficulties involved (e.g., insurance and cooperation of the operators). However, these were conducted in Calgary with a fair degree of success. These surveys gave special O-D data and detailed observations of performance of particular vehicles.

Interviews With Truckers—The bulk of the O-D information came from trucker interviews, which are a standard form of survey procedure for this type of study.

End-Point Facility Surveys—The end-point facility studies have been undertaken in special limited cases in the past. To our knowledge the Calgary work demonstrated the first widespread use of such studies. More than 300 end points throughout the city were surveyed. An interesting observation in Calgary is that there are many laneways in the city and, because of this, there are very few cases of trucks parking illegally or blocking traffic on city streets. Most use the back entrances accessible from the laneways. Procedures were developed so that all end points within a given laneway could be surveyed in 1 day.

The data generated in Calgary were checked by using edit-check computer programs developed for this purpose and are now in the form that can be analyzed.

Phase 3 Work

As part of phase 3 the Calgary data will first be reduced to provide inputs required by the micromodels and macromodels, finalize the proposed urban goods classification system, modify the logic to the micro and macromodels if required, and possibly develop a demand generation or distribution model or both.

As an interesting by-product of this work a statistical profile of trucking operations in Calgary will be available. It is expected that interesting conclusions can be drawn on the influence of city size on trucking operations. Certain other model inputs will also be generated at this time such as the link-zone system for the city. The candidate improvements will then be tested and recommendations for future government and industry action will be proposed.

URBAN GOODS CLASSIFICATION SYSTEM

Within the urban area thousands of different commodities are moved and practically all by trucks. By defining a truck in terms of body type, wheel and axle configuration, capacity, and special characteristics (e.g., refrigerated), some 100 separate vehicle categories can be distinguished. Clearly, to collect, assemble, analyze, and use information on commodities and vehicle types require an urban goods classification system that has a manageable number of categories.

Such a classification system should identify goods in terms of their transportation requirements. It should also be structured to be useful in modifying or rationalizing the urban goods rate structure as well as streamlining the paper work procedures.

None of the existing commodity codes satisfies these requirements. Present codes such as the STCC used in the United States describe the commodity in terms of what it is and not in terms of its transportation requirements. An experimental classification system was therefore developed during phase 1. Table 2 gives a summary of the second

Figure 3. Sample macromodel output.

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                                        SYSTEM SUMMARY

LINKS (WITHOUT CONGESTION)                 TRUCKS    PASSENGER VEHICLES      TOTAL

        TON MILES                         35822.90          4130.69       39953.61
        VEHICLE MILES                     33725.17        293990.75      327715.94
        COST($)                            6981.39         12660.39       19641.88
        TIME(HRS)                          1714.89         13811.97       15526.85

LINKS (WITH CONGESTION)

        TON MILES                         38086.38          4749.96       42836.41
        VEHICLE MILES                     37298.00        335412.75      372710.75
        COST($)                           24521.97         14515.88       39038.07
        TIME(HRS)                          6097.10         63427.69       69524.44


LINK CONGESTION COSTS($)                  17540.59          1855.50       19396.19

LINK CONGESTION TIME(HRS)                  4382.21         49615.72       53997.59



ENDPOINTS

        NUMBER SERVICED                5650.82
        COST($)                       13520.57
        TIME(HRS)                      3380.16
        PASSENGER DELAY(HRS)          11546.22

ZONAL OPERATIONS

        NUMBER OF DRIVING TRIPS        9921.60
        VEHICLES MILES                 9921.60
        COST($)                        2092.83
        TIME(HRS)                       514.98

TOTAL TRUCKING COST($)                40135.37

TOTAL TRUCKING TIME(HRS)               9992.23

TOTAL TRUCK MILES                     47219.60

TOTAL PASSENGER DELAY(HRS)            61161.94
```

Table 1. Vehicle types in Calgary.

		Body Type											
Truck Configuration	Wheel-Axle Configuration	Pickup	Panel	Step-Van	Van[a]	Stake	Tank	Dump	Lowbed-Flatbed	Box-Hopper	Single Purpose	Refrigerated Van	Total
Straight truck	2 axles, 4 wheels	54.5	2.1	1.6	15.0	1.5	—[b]	—[b]			0.5	—[b]	75.2
	2 axles, 6 wheels			0.4	5.5	5.4	0.6	1.7	—[b]		1.7	0.1	15.4
	3 axles				—[b]	0.3	0.1	2.4	—[b]	0.1	1.2	—[b]	4.1
Tractor trailer	3 axles				0.6	0.1	0.1	0.1	0.1	—[b]	—[b]	—[b]	1.0
	4 axles				0.4	0.1	0.2	—[b]	0.3		—[b]	—[b]	1.0
	5 axles				0.6	0.1	0.5	0.2	0.9	—[b]	0.1	—[b]	2.4
	6 or more axles				—[b]		—[b]		—[b]	0.3			0.3
	Double bottom				—[b]		—[b]		—[b]				—[b]
	Total	54.5	2.1	2.0	22.1	7.5	1.5	4.4	1.3	0.4	3.5	0.1	99.4

[a]Includes ½-ton vans in the 2-axle, 4-wheel category.
[b]Less than 0.1 percent.

Table 2. Suggested urban goods classification system.

Category No.	Commodity Group	Examples and Description	Vehicle Type: Body Type	No. of Axles	No. of Wheels
S1	Service vehicle, mobile	Construction foremen's pickup and other such vehicles with commercial license but used to large degree only to transport the driver	Pickup or station wagon	2	4
S2	Service vehicle, special	Plumbers, carpenters, telephone repair truck that must carry both men (including driver) and tools or materials for them to use, usually with special built-in fittings or equipment	Panel, pickup, or van	≥2	≥4
V1	Pickup and delivery, single commodity (excluding food)	Usually for small packages, such as mail, for local delivery	Usually van or step-van	2	4
V2	Pickup and delivery, one-man, local	Eatons, local cartage, etc., express co.	Usually van or step-van	2	4
V3	Pickup and delivery, two-man, local	Eatons, local cartage, etc., moving van	Van or stake	2	4 or 6
V4	Distance van	Intercity moving van and intercity van cartage	Van on trailer	3, 4, or 5	10 to 18
V5	Food, local	Frequently single commodity, especially name-brand beverage	Usually van	2	4 or 6
V6	Food, distance	Large food trucks, refrigerated or not	Usually van or truck	3, 4, or 5	10 to 18
K1	Building materials, straight	Various building materials	Stake	2	4 or 6
K2	Building materials, trailer	Various building materials, lumber, etc.	Stake, low-bed on flatbed (trailer)		14 to 18
K3	Equipment and other, straight	Machinery, equipment, and all other materials (excluding building materials)	Stake	2	4 or 6
K4	Equipment and other, trailer	Machinery, equipment, and all other materials (excluding building materials)	Stake, low-bed on flatbed (trailer)	5[a]	14 to 18
D1	Common earth	Machinery, equipment, and all other materials (excluding building materials)	Dump	2	6
D2	Common earth, tandem	Machinery, equipment, and all other materials (excluding building materials)	Dump	3	10
D3	Sand, gravel, ore	Processed earth materials	Dump	2	6
D4	Sand, gravel, ore, tandem	Processed earth materials	Dump	3	10
P1	Petroleum, straight	Gasoline, fuel oil, etc.	Tank	12[a]	6[a]
P2	Petroleum, trailer	Gasoline, fuel oil, etc.	Tank	5[a]	18[a]
P3	Special transport, straight	Livestock, garbage, concrete	Special	2 or 3	
P4	Special transport, trailer	Motor vehicle carriers, cement hopper, container carrier	Special	5[a]	
P5	Special equipment	Snowplows, road maintenance machinery, military vehicles, wrecker	Special	2 to 5	
P6	Mobile home		Special		
W1	Manually propelled	Bicycles, horse- or man-drawn vehicles	Various		
W2	Miniature and motorcycle	Motorcycles, scooters, etc.	Various		
W3	Unclassified straight		Various		
W4	Unclassified trailer		Various		

[a] Usually.

edition of this system. It should be noted that this proposed system has been specifically tailored for the study of goods movement in North American urban areas. That is, it is aimed at testing candidate improvements by using the URBGDS package. It is not necessarily well suited for intercity transport studies. As part of the phase 2 data collection, survey questions were designed so that the preliminary system given in Table 2 could be finalized.

At first glance, this may look more like a vehicle classification system than a goods classification system. This is because we have found that the most practical way of relating goods to their transport characteristics is to identify the vehicle in which they would likely be transported. Thus, for example, "pickup and delivery, one man, local," identifies a commodity class by size and type of packaging such as would go in a local pickup and delivery van with one man operating the van. Both vehicle and commodity can be practically identified in surveys. One criterion for the system has been that no category should include less than 1 percent of the total movement. On the other hand, no category should include more than perhaps 10 or 15 percent of the total. Thus, one arrives at something like 25 categories. The system of classification of commodities is important to making progress in urban commodity flow research. It is hoped that this suggestion will stimulate discussion.

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BASIC DATA NEEDS FOR URBAN GOODS MOVEMENT ANALYSIS

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•THIS PAPER describes the types of data required to deal with three kinds of urban goods movement problems. Sources of data and procedures for obtaining information have been discussed elsewhere (1, 2). It should be noted that the coverage of these sources changes from time to time and that new technology, such as the application of atomic energy, carriage of new automobiles on trilevel cars, or storage and ocean transport of liquefied natural gas, will change both the relative importance of each mode and the source of relevant information, so the analyst will have to review the field thoroughly before he commits himself to a study procedure.

The need for data bearing on the major institutional problem in the freight field is also described.

WHAT IS THE PROBLEM AND HOW IS IT ANALYZED?

There are four basic reasons for the relative lack of success experienced by those of us who collect and analyze urban freight data for planning purposes.

1. The kinds of problems we were going to deal with have not been determined beforehand.
2. Because there are many individual freight problems in large urban areas, many individual data collection efforts are required.
3. There was formerly a tendency to try to develop a comprehensive urban goods movement model to predict urban goods movement action. This assumed a homogeneous behavior pattern that has not been found to exist.
4. There are many institutional barriers to change, not the least of which is the fragmentation of ownership and responsibility found in intraurban trucking. This is an important obstacle in the way of executing any plan to improve intraurban freight distribution.

Types of Problems

As experienced by tri-state, there are three major kinds of goods movement problems, other than institutional.

Generalized Regionwide Planning Questions—"How does the system work?" These questions deal with what it takes to keep the region functioning and what it will require in the future. Information is needed on total inputs such as food, fuel, and other freight, as well as on the capacities of existing systems. Similar information is required for both intraregional demand and the systems that carry it and the region's outputs and how they are taken care of.

Identification of Goods Movement Problems for Remedial Action—"What needs fixing?" This step requires more detailed information on system characteristics of each mode and the nature of its traffic. In other words, the analyst must determine what part of the job each mode does, how it does it, and how much it costs. The rate of growth or decline of parts of the system should also be determined.

Proposing or Evaluating Solutions for Individual Problem Areas—"How can we fix it?" Examples of such projects might be a revised solid waste collection scheme, improving freight transportation in the garment center, or a consolidated lighterage system in New York harbor.

Institutional problems become critical at this stage.

Analytical Approaches

Until recently papers on the amount and kinds of information needed to bring the function of goods movement within the urban planning process usually stated that the subject had been almost totally ignored. They also state that, because goods movement decisions are made rationally by profit-minded entrepreneurs, it should be possible to model goods movement with more accuracy than has been achieved in modeling personal travel behavior, if enough of the right information is available.

It all depends on what you try to model. Except for freight generated by personal consumption, for which there is some evidence of stability (3), available evidence shows that the freight problem is not one problem but dozens of problems, with a different mix for every urban area. Is New York City's garment center duplicated anywhere else in the country? What city other than Chicago, or perhaps St. Louis, has the problem of exchanging 2,500 piggyback trailers per day among 13 railroads over its street system? How does Pittsburgh handle the interplant transfers necessary to keep its steel-making and heavy manufacturing operations going? Is any other freight problem like that of picking up solid waste and getting it to a disposal area? Can that problem be handled the same way in a crowded Manhattan street as in the wide open spaces of Scottsboro, Arizona? In actual practice the two operations are quite different.

In the face of such diversity we must conclude that any successful goods movement model either will be limited to goods movement arising directly from personal consumption or will be a very specialized, hand-tooled piece of equipment.

DATA NEEDS

In complex urban areas it is impractical to try to collect data for the three types of problems all at once. Data for each approach supplement work on the other two, but the main message to the freight planner must be to pick a target and shoot at it.

The following discussion is, of course, heavily conditioned by experience in the tri-state region.

Data for Regionwide Planning

All of these data should be compiled with the purpose of forecasting the characteristics of the region at some target year or years in the future—15 to 30 years distant—to determine what needs will have to be met in that time span.

Inputs—Total inbound freight volumes should be compiled by mode and by commodity groups. The detail required will depend on the forecasting problem.

Fuel data will have to be collected not only by mode but by major type of fuel within mode. Thus, waterborne petroleum must be broken down to residual, distillate, gasoline, and jet fuel inasmuch as each fuel type depends on different factors. Residual use depends on electric generation and industrial power, distillate on floor space, and gasoline on vehicle-miles, and each has separate growth rates. We have also found it necessary to expand our subject matter to include all kinds of fuel and power, including natural gas, nuclear power, and power imported by wire. All these must at some point be converted to a common basis, such as Btu's or coal tonnage equivalent, for forecasting future needs.

Other conventional freight inputs, such as food, raw materials, and whatever else is of substantial importance to the region, that are subject to different growth influences must be compiled separately. Other inputs such as fresh, potable water and electric energy consumed should be developed.

The cost of service via each mode and for important segments of each mode (general cargo versus bulk transport by water) should be established. The major characteristics (networks, range of services provided) and the capacities of each mode should be described.

Internal—Internal freight volume by mode should be established as should the cost of service by mode. The major characteristics of the distribution networks and their capacities should be developed: highway, water, gas and oil pipeline, water and electric energy. The output of waste and systems for its removal or control at the point of origin should be determined. Each of these will follow its own trend.

Outputs—Volumes, characteristics, and capacities of outbound traffic should be developed. Particular attention should be given to the systems that carry important segments of the region's output and that are thus critical to the area's economy. Separate forecasts of volume may be necessary for the shipments of the area's leading industries.

Waste load, in terms of solid waste, waste heat, waste water, and air pollution emissions, their burden on the environment, and the characteristics and costs of controlling them may be considered a part of the goods movement analytical framework, especially if they have not been compiled before in a comprehensive regional analysis. These growing problems will certainly affect the way future facilities are arranged on the landscape.

Data for Identifying Goods Movement Problems

The purpose of this endeavor is to determine whether the freight system can be made to work better. Data for important subdivisions of each mode should now be developed and the competitive relations established. Piggyback and containership volumes, costs, and capacities should be obtained if these are important elements of the area's traffic. Service and cost via these modes should be compared with service and cost via over-the-road truck and air cargo. Capital facilities plans by both public and private agencies should be compiled and compared with forecasts of traffic to determine whether such plans are reasonable. The cost and service of truckload versus less-than-truckload service, public and private, should be developed. The adequacy of capital plans of private utilities and fuel suppliers should be reviewed against consumption forecasts, and their progress in obtaining necessary sites should be checked.

These data should be reviewed to ascertain the largest single cost elements in the system, which parts of it are big enough to worry about, which parts are showing unhealthy trends in traffic or in cost of service, where there is undercapacity or overcapacity, and which parts probably cannot be influenced by public policy or private profit.

Armed with this information the analyst can establish hypotheses on how his region's freight system can be improved, and he can review the reasonableness of proposals originating elsewhere.

Data for Particular Freight Transportation Solutions

This type of problem requires data collection efforts specifically designed to yield present and future volumes, present and future costs, and present and future service standards under both the current system and the one proposed to replace it. The analyst must build a very specific model of the freight system before and after the proposed change. Provision should be made to collect data after the change to determine whether things are working out as planned.

At this scale the analyst must come to grips with the way the freight system satisfies its customers. His proposed solutions must satisfy the shipper, in terms of service and cost, and meet requirements of urban planning, such as releasing land, reducing street load, and so on. He will often have to go into the customer's establishment to determine required frequency of service, times of desired pickup and delivery, etc.

THE LEADING INSTITUTIONAL PROBLEM IN FREIGHT

In the tri-state region the local trucking function costs about $3 billion per year to perform. Nationwide trend data indicate that this cost is increasing rapidly. Local trucking is the one major area of transportation in this country that is getting less efficient year by year (Table 1).

Most local trucking is performed by people who own the goods they are transporting rather than by for-hire carriers, and the management of the function is fragmented among thousands of individuals and small companies. In the tri-state region, one-third of the trucks belong to single-truck fleets. Government participation in the function is low, both in ownership of trucks and terminals and in regulation.

Table 1. Selected transportation factors as share of gross national product (4).

Truck Only	Combination Truck-Transit
Loading on truck	Loading on truck, truck movement to transit station, transfer to transit vehicle[a]
Truck movement to destination	Transit movement to station near destination, transfer to truck[a], truck movement to destination
Unloading from truck	Unloading from truck

[a]If transit right-of-way is not at-grade with roadway, special ramps or materials handling equipment are required for the transfer.

All of this produces a situation in which it is very difficult to develop plans in the first place and to find a leverage point to get them into effect in the second. There is no federal funding program, no centralized management that can be persuaded, and no system of economic regulation to control activities.

It seems to be essential to deal with the issue of the proper institutional framework to guide and control local trucking. Certainly available evidence indicates that costs are getting out of control. We need a great deal more evidence than we have now on effective ways to organize this function on an areawide basis. Until this factual basis is developed, it will be necessary to take full account of such organizational problems at the local level as we develop the information necessary to plan specific projects of limited scope.

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SOME FALLACIES IN URBAN GOODS MOVEMENT

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ABRIDGMENT

•INTEREST in urban goods movement has grown rapidly in recent years, probably at a faster rate than the growth of factual knowledge. As a result, some misconceptions and fallacies are arising, particularly among those new to the subject. The purpose of this paper is to explore a few of these fallacies.

All trucks are used to move goods.

Statistics for 1970 show 108.4 million motor vehicles registered in the 50 states; 18.7 million of these were designated as trucks. The figures for California for the same year are 11.9 million and 2.0 million respectively (1). Of the 2 million trucks in this state, however, 1.3 million or about ⅔ are 2-axle, 4-wheel pickups used mainly as personal vehicles, reflecting the owner's preference for the pickup body style over the van or station wagon, not his need for a goods movement vehicle (2). This conclusion is borne out by interviews conducted recently by the California Department of Motor Vehicles, which showed that more than 70 percent of the pickup trucks intercepted were not moving goods at all but were used for trips between home and work or for personal business and recreational purposes (3). The pickup's popularity used to be centered in rural areas; in recent years, and particularly with the advent of the camper, it has spread to urban areas as well.

Among the other, nonpickup trucks, there is an additional group not really engaged in the movement of goods: those that perform what is called the transportation of services. This refers to a vehicle carrying one or several workers and a substantial amount of tools, equipment, and supplies moving to a job site where crew and equipment perform maintenance, repair, or some other service. Specialized equipment used for work on utility lines is an example. Upon completion of the job, the vehicle, load, and crew proceed to the next job or return to their home base. The weight of parts and supplies used at the job site is generally small in relation to vehicle gross weight. To call this type of operation transportation of a service may appear redundant inasmuch as transportation itself is a service; the key element here is that the demand for transportation is derived primarily from a demand for some other service, not from a demand for goods. An additional percentage of the total registered trucks belongs to the service category. Thus, more than 50 percent of the vehicles described as trucks in California motor vehicle statistics are not engaged primarily in the movement of goods.

Goods movement-generated congestion in the CBD is on the increase.

Metropolitan areas are growing, and so are the CBDs of many cities, particularly in the West. It would seem to follow that urban goods movement in the CBD is growing also and with it the congestion it generates. There is some evidence that this is not so. A comparison of cordon counts of trucks entering the San Francisco CBD on a weekday between 10 a.m. and 6 p.m. shows, in fact, a decline over an 18-year period from about 31,000 to 13,000 trucks (4). Here truck refers to units with at least two axles and six wheels and to combinations of power and trailing units. The CBD boundaries are generous and include a support area that is in transition from light industry and warehousing to office buildings.

Similar data for the Chicago CBD, based on a 12-hour day, show that the number of service vehicles (motor vehicles other than cars, taxis, and buses) during the same

18-year period fluctuated between 24,000 and 16,000 and declined gradually (5).

The volume of vehicles entering the CBD is only a rough indication of the congestion caused by goods movement vehicles. A more precise evaluation would require knowledge of other factors, such as the distribution of the entering vehicles by time of day, length of stay, size of vehicles, number of stops, location of stops, and type of parking (curb, angle, or off-street). But the trends in volume of vehicles can serve as a warning against the assumption that truck congestion varies directly with such indicators of CBD size as land area, floor space, or employment.

Both person movement and goods movement into the CBDs of western cities appear to be changing in magnitude as well as in kind. White-collar employment is rising as blue-collar employment and shopping are shifting outward. As more goods are produced and consumed away from the CBD, the need for massive goods movement in the center of the city may decline. There may be benefits both to the CBD and to goods movement resulting from this gradual separation.

Consolidation of urban goods movement will produce major benefits to all concerned.

The dominant image of the urban goods movement problem in the minds of many observers is that of a string of trucks, each loaded to only a fraction of its capacity, winding their way through congested streets and alleys, competing with other vehicles for movement space and with each other for curb and dock space. In this setting, the idea of some sort of consolidation of goods movement has a powerful appeal, much like that of mass transit as a reliever of person movement congestion. Consequently, most proposals for improvement of urban goods movement contain some aspect of consolidation.

1. Platform operations for intercity less-than-truckload shipments consolidated at a union terminal,
2. Pickup and delivery services in a given sector of the urban area performed by a single carrier, and
3. Strict control of entry into the field of urban common carriage, accompanied by restrictions on private carriage.

There is little doubt about potential benefits from consolidation, but there is some doubt whether the associated disbenefits and costs are fully recognized. Solid quantitative evidence is difficult to obtain, but the following listing contains some of the less positive aspects of consolidation.

1. Decreased frequency of pickup and delivery service—If the urban area is served by a number of competing common carriers, the shipper is likely to be served by several regular pickups spread over a period of time as well as by the occasional late call for a "hot" shipment. Consolidation is likely to result in once-a-day pickup or delivery stops, and these stops may occur at a time that is inconvenient for the shipper or receiver of freight. Decreased frequency is also bound to increase total time in transit for some shipments.
2. Dock space requirements—A likely consequence of consolidation is change in the traffic pattern across the shipper's or receiver's dock. Sudden surges of freight will replace the more evenly distributed flow he experiences under present arrangements. He may need less space for trucks on the street side of the dock but more space for freight on the plant side.
3. Terminal size and location—Terminals seem to be getting bigger each year. Somewhere along the line, we will reach maximum economic size; perhaps we have passed it already. Though we may not know precisely what the optimal size is, it appears safe to state that no major urban area could be served economically by one vast, consolidated terminal. This means that we shall have to go to multiple terminals, perhaps one or more at each gateway. But this implies either a large volume of transfers between terminals or overlapping pickup and delivery routes, or both—in any event a less-than-ideal system that will cancel some of the potential gains of single-terminal consolidation and that may end up looking not too different from the status quo.
4. Management problems—An analysis of consolidation may make allowances for the foregoing points but still come up with appreciable paper savings. We should keep in

mind, however, that there are numerous recent examples in both public and private sectors where consolidations have been effected but have fallen short of delivering the economies of scale that seemed so convincing when the consolidation proposal was first considered. We have seen it at the federal level in the Departments of Transportation and Defense, at the local level in school district unification, and in the private sector in rail mergers. There is an art to managing large, complex systems; it must be learned, and the learning period appears to be long and costly. After many years and even with considerably enlarged managerial freedom, the Postal Service is still struggling to master its giant system. It is safe to predict that any attempt to consolidate urban goods movement will encounter its share of managerial and technical problems and that these will take time to resolve.

These points do not invalidate the inherent logic of consolidation, but they should point to the need of scaling down our expectations of net benefits to a realistic level.

Consolidation of urban goods movement will relieve downtown congestion.

Assume, for the moment, that we have conducted a complete analysis of the benefits and costs of consolidation of urban goods movement, that the benefits clearly outweigh the costs, that we have effective cooperation from all concerned, and that we are able to implement a consolidation program successfully—and these are big assumptions indeed. All incoming less-than-truckload freight is intercepted at gateway terminals and distributed by a joint venture of common carriers so that there is no overlap of delivery routes at all; pickups are handled similarly. Will we have alleviated CBD congestion?

There are little actual experience and even fewer data for an answer to this question. Certain basic factors, however, are readily apparent. Although we may reduce the number of common carrier vehicles dispatched into the downtown area, we also face the possibility, noted earlier, of an increase in total elapsed time for local and intercity movements. For some shippers and consignees, that increase may be intolerable, and they may decide to shift to proprietary operation, thus adding to CBD traffic volumes. More significant yet, there is a seemingly inexhaustible reservoir of automobile drivers who are conditioned to a certain level of congestion and who abhor a vacuum. They stand ready to take advantage of any apparent easing of traffic until it again reaches that level of congestion to which they have become accustomed. Consolidation of one segment of downtown vehicle traffic does not assure an absolute decrease in traffic volume. Permanent relief of CBD congestion is unlikely.

Urban goods movement can be improved by using rail rapid transit facilities during off-peak hours.

With some regularity, we hear and read proposals to use rapid transit systems for goods movement, especially to serve the CBD during nighttime hours. One motivation for such proposals is readily apparent: Capital costs and operating expenses of rapid transit systems are governed by the need to accommodate two very sharp peaks during the daily rush hours; ridership is low between the peaks and during nighttime hours; thus, the system is underutilized. Just as a backhaul is attractive to the trucker even if it pays only for fuel and oil, any form of off-peak utilization is inviting to the transit operator. The operational problems, however, are enormous. Even without cost analysis, a review of the steps involved indicates the obstacles. Movements by truck only and by truck-transit combination are compared in Table 1. If we add to this comparison the fact that at night, when transit facilities are available, surface streets are also free of congestion, the benefit of transit use then becomes even more dubious.

Some decades ago, integrated rail systems transported persons and goods in both short- and long-haul operations. Profound changes have occurred since, and we now have two entirely different systems: privately owned railroads transporting goods over long distances and publicly owned rapid transit systems transporting passengers over short distances in metropolitan areas. To retrofit existing rapid transit systems for goods movement appears futile. Even the design of future systems for dual use of persons and goods appears to be a mismatch for our motor-vehicle-oriented metropolitan areas.

Table 1. Comparison of urban goods movements from an off-transit origin to an off-transit destination.

Factor	Percentage of GNP				Change in Relative Share
	1959	1964	1969	1970	1959-1970 (percent)
Passenger bill	10.79	10.36	10.64	10.19	-5.6
Freight bill					
All intercity freight	6.96	6.38	5.69	5.71	-18.0
Local trucking	2.83	3.21	3.27	3.65	+29.0
Total freight	9.79	9.59	8.96	9.36	-5.4

So much for some of the more widespread fallacies. If there is one central theme here, it is this: The obvious and simple answer to a question or problem is not necessarily the correct one. Whereas this is hardly news to planners, engineers, and analysts, it bears reiterating in the context of urban goods movement.

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CAN REGIONAL PLANNING IMPROVE TRUCK TRANSPORTATION?

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ABRIDGMENT

•IN RECENT YEARS, urban and regional transportation planning agencies have significantly increased the priority attached to studying freight transportation. Whereas a few years ago it was rare to see commodity movements afforded more than passing mention in reports, now urban transportation agencies are considered derelict unless actively engaged in the study of freight. Given the importance of freight transportation in the overall urban system, this trend is commendable.

It is difficult to generalize the varied approaches taken in the study of freight transportation. However, the literature presents widespread acceptance of certain common assumptions, including the following principles:

1. The main role of regional transportation planning agencies is to develop and evaluate large-scale alternatives for expediting freight movements and to eliminate conflicts in the joint transport of people and goods (1, 2, 3, 4, 7).
2. Great emphasis is properly placed on the development of an adequate truck travel model that will permit forecasting future truck trips associated with various planning alternatives (4, 5, 6, 7).
3. The workhorse of data base development is the truck survey, in which the information collected describes daily itineraries of a representative sample of trucks (8).

An objective review of these assumptions leads to a very basic question: Are the resources of regional transportation planning agencies being employed most effectively to help solve urban freight problems? The conclusion is that they are not because there is too much mimicking of people movement studies and too little emphasis on the actual nature of freight transportation problems.

To support this contention, we shall review the three principles listed. In each case we shall ask why. Does careful examination of the problem suggest that the principle is justified? If it is not, how should the resources of planning agencies be reallocated to increase the likelihood of solving some of these freight transportation problems?

WHY STUDY LARGE-SCALE ALTERNATIVES?

Urban and regional transportation studies were created in response to the difficulties inherent in project planning. It was recognized, correctly, that major arterials, expressways, and transit lines in an urban area are an indivisible system and that proposed changes to any single facility potentially affect some others. This led to the concept of the network alternative, a single proposal containing a combination of the options available for individual facilities. Analyzing network alternatives is useful because sufficient resources are not available to test system response to all combinations of the many individual options and because it provides a suitable framework within which to test major highway and transit policy alternatives.

If for a moment we ignore the issue of freight traffic on the regional transportation system, there are still a number of large-scale issues that can be studied. For example, suppose that public regional truck terminals were to be established for transshipment. Or suppose that carriers were somehow made to consolidate less than truckload pickups and deliveries. How would these and other possible large-scale innovations affect system efficiency?

These are definitely interesting questions, but are they really relevant? How many cities are likely to have regional terminals in the foreseeable future, even if the transportation planning agency decides that it is a good idea? Probably very few. Politically, how feasible is any plan that shows the private trucking industry how to consolidate its operations? Probably not very. It seems that in most cities the probable payoff from studying such grand schemes is questionable. While the theoretical benefits may be large, the likelihood of obtaining them is small, and, consequently, the justification for using resources to study such questions is questionable.

It seems more desirable to concentrate on issues of which the potential benefit to freight transportation, both theoretically and practically, is large. The less practical alternatives should not be forgotten, but they should receive attention in proportion to their likely payoff. Other issues with larger likely payoffs should receive proportionally more attention.

HOW NECESSARY IS A TRUCK TRAVEL MODEL?

In discussing large-scale analysis, we cannot ignore the backbone of transportation study activity, the analysis of traffic flow on the regional transportation system. Since their inception, studies have attempted to forecast personal travel on regional transportation systems. It seems logical to extend this capability to commercial movements through the development of truck travel models.

Or is it? After all, why do studies engage in these forecasting activities in the first place? In the case of traffic, the reason is that there is no other way to predict likely capacity bottlenecks in future systems, which can be prevented by controlling current investments. Studies have proved that bottleneck-causing traffic levels occur mostly in the daily commuting period and, in some places, during the Sunday night recreation rush (4, 9). By and large, these are not the times that commercial trucks constitute a major component of the traffic. It has been shown that the percentage of trucks in peak-period traffic volumes is fairly small, probably not even so great as the percentage of accuracy of traffic forecasting procedures themselves.

Ideally, the rather costly activities performed by regional transportation studies are undertaken to permit more informed decisions on transportation system investments. At the point that further analysis contributes little additional help in the selection among available options, the analysis should be curtailed. In my estimation, the contribution of truck travel models falls into this category except in a few atypical urban areas.

On the other hand, almost all sizeable cities have a significant truck congestion problem. The problem occurs in high-density commercial areas where the size and poor maneuverability of trucks in the traffic stream cause bottlenecks as do loading and unloading operations. This seems, in most cities, to be the truck traffic problem, and urban transportation studies seem to be in an excellent position to do something about it.

ARE TRUCK SURVEYS USEFUL?

The truck traffic problem must be recognized for what it is, a local not a regional phenomenon. For this reason, we find it hard to justify the cost and considerable aggravation of undertaking regional truck surveys. Except in those few urban areas where a regional truck travel model would contribute significant insight into the differences among reasonable transportation investment options, the effort is better spent collecting data more pertinent to the problems at hand.

But what data are helpful in analysis of truck traffic problems? This, of course, depends on the problems. In areas where the major problem is traffic congestion caused by loading and unloading operations, the most pertinent modeling analysis probably would be a trip generation study oriented to the different land uses in the area. Because the emphasis here is on the stops rather than on the trips, the most suitable data collection technique would be to survey the comings and goings of trucks at selected establishments, ignoring the remaining itineraries of the trucks. From these data, one could determine the ability of different schemes to accommodate deliveries, without having to forecast truck travel on transportation networks.

On the other hand, in cities where adequate off-street loading facilities are available, the critical problem may be traffic congestion caused by truck trips. In these cases, both trips and stops are important, and a truck travel model is not needed to estimate network flows. However, the flows of interest are those on the city street network of the problem area, not those on the regional transportation network (10). The appropriate data collection approach would be similar to the traditional truck survey, but the sample would include only the trucks traveling in the problem area.

ROLE OF THE REGIONAL PLANNING AGENCY

One may reasonably ask why a regional planning agency would become involved in small area studies that are the domain of city traffic engineers. This is a difficult and controversial issue; regional agencies should not unnecessarily usurp local functions. In this case, however, it seems that the importance of these types of problems and the unique capabilities at the regional level combine to indicate that some regional involvement is appropriate.

All issues considered, the most productive role for regional planning agencies in dealing with most truck congestion problems appears to be the following:

1. Technically, regional planning agencies should act as consultants in designing local traffic studies and in undertaking suitable data collection. Because of its nature, the regional agency would be able to staff experts in freight traffic problems who could help local officials determine how to approach truck traffic problems. In addition, the regional agency is the most logical repository for land use and commercial activities data needed by the local studies. This is because the regional agencies have facilities for ongoing data base management.
2. Politically, regional planning agencies can use fiscal persuasion to convince local agencies to recognize the actual priority of their freight transportation problems and to take appropriate action to find solutions. Of those concerned, the regional agency is usually in the best position to open dialogue when regional priorities for efficient freight movements conflict with local interests.
3. Financially, regional planning agencies should subsidize local freight studies insofar as these studies help to alleviate regional problems. In general, regional planning funds should be allocated in proportion to the expected payoff in improved conditions. If this criterion requires that some regional planning funds be shifted voluntarily to local planning agencies, so be it.

OTHER AREAS OF INVESTIGATION

As a final topic, several other issues seem to be valid areas of concern for regional transportation planning agencies. These topics are included to broaden perspectives on what may be considered appropriate and useful activities at this level. No attempt is made to assess the relative priorities of these ideas. It is sufficient if they suggest that the full potential of regional planning agencies is not being realized.

COST ALLOCATION

The question of what are fair-share payments for public transportation facilities is perpetually controversial. Traditionally it has been up to state government to devise a formula for splitting road costs among the various beneficiaries, and numerous reasons suggest that this assignment of responsibility is proper. Nevertheless, there may be an active but yet unemphasized role to be played by regional transportation planning agencies.

For example, vehicle fees for trucks are generally assessed (11) on the basis of miles driven (fuel tax) and weight (registration fees). This scheme is an equitable compromise between trucking and automobile interests, statewide, but perhaps it introduces some inequities when evaluated in terms of the urban-rural split. First impressions suggest that intraurban trucks, which are light but somewhat bulky and which travel few miles compared to their interurban counterparts, possibly do not generate public revenue in proportion to their use of the roads, much of which involves parking.

It seems desirable for regional transportation planning agencies to participate in seeing that possible inequities along these lines be rectified. Of all institutions, these agencies seem the most appropriate and capable to represent urban transportation interests in this regard. Although cost allocation questions are settled at the state level, it seems that urban studies should take the lead to promote consideration of these types of issues.

ANALYSIS OF EXTERNAL COSTS

Another potential area of concern for urban and regional planning agencies is the potential impact of internalizing some of the so-called external costs of transportation and, in particular, of freight transportation. Of current interest is the effect on the economics of freight transportation of mandatory reductions in air and noise pollution. Along similar lines, we need to know the impact on trucking of a rise in running costs due to fuel shortages.

Clearly, these occurrences would raise the costs of trucking, but how would they affect the final costs of transported goods? Would consolidation of companies and other similar effects eliminate some of the added costs through increased efficiency, or would all of the cost be passed on to shippers and, ultimately, to consumers?

Such questions would seem to be of importance to regional studies inasmuch as pollution abatement and, to some extent, energy shortages are regional issues; however, it is likely that few studies have the resources to explore these questions alone. These are really questions for national-level research. However, the regional agencies can and should play a major role in encouraging, sponsoring, and monitoring such investigations to ensure that the knowledge gained is applied at the urban planning level.

INNOVATIONS IN FREIGHT HANDLING

Encouraging innovation is another useful function of regional planning agencies. In this country, private enterprise has traditionally performed well in developing and advertising new concepts in hardware technology. However, the private sector is not particularly efficient at spreading word of nonhardware developments, such as new structures of coordination and cost sharing among freight handlers, innovations in work scheduling to reduce congestion delays, and so on. It seems desirable for regional transportation planning agencies to keep abreast of such breakthroughs throughout the world and, through seminars, newsletters, and the like, to inform industry and, in certain cases, to encourage similar local experimentation.

CONCLUSION

The purpose of this paper is to promote a reevaluation of the activities of urban and regional transportation studies in dealing with freight transportation. These agencies are now preoccupied with elaborate analyses of schemes to improve freight movements at the regional level at the expense of ignoring other often more important problems at other levels.

In this discussion, we have looked at some problem areas that could be improved through the involvement of regional transportation planning agencies. Interestingly, most are not, by their nature, regional problems. Truck congestion is basically a localized phenomenon, most suitably analyzed within a framework far more detailed than that provided by a regional-level study. Other issues, such as equitable cost allocation and the impacts of pollution abatements, are general economic and policy issues most suitably analyzed at the state or national level. Regional agencies should recognize this and design their program of activities accordingly. In this way, the valuable resources of these organizations can be allocated to pursuits that hold the most promise for meaningful accomplishment.

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